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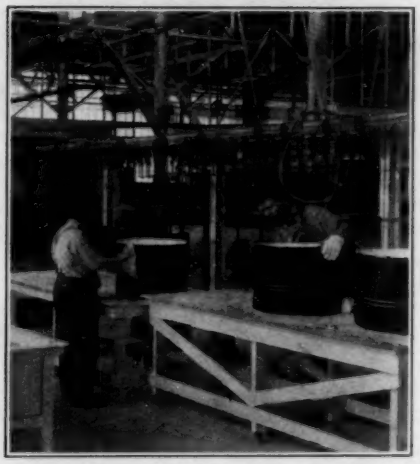

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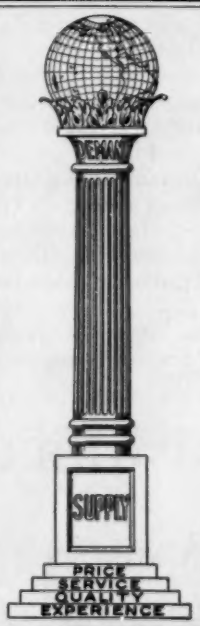

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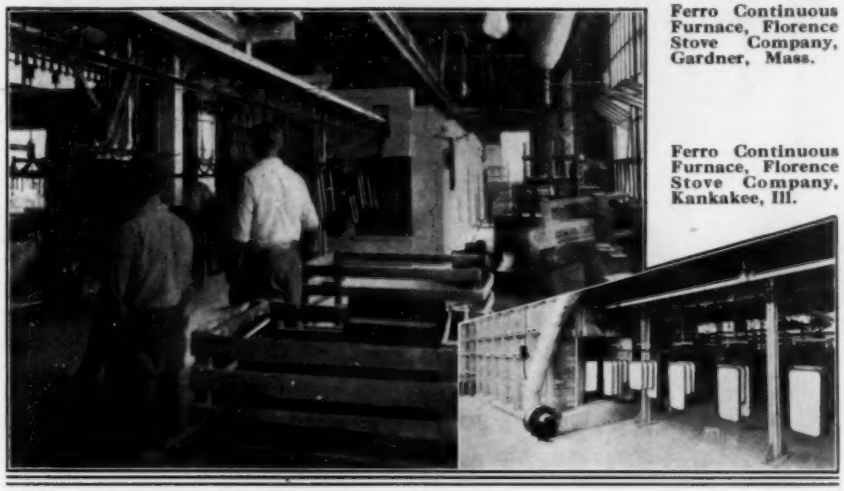

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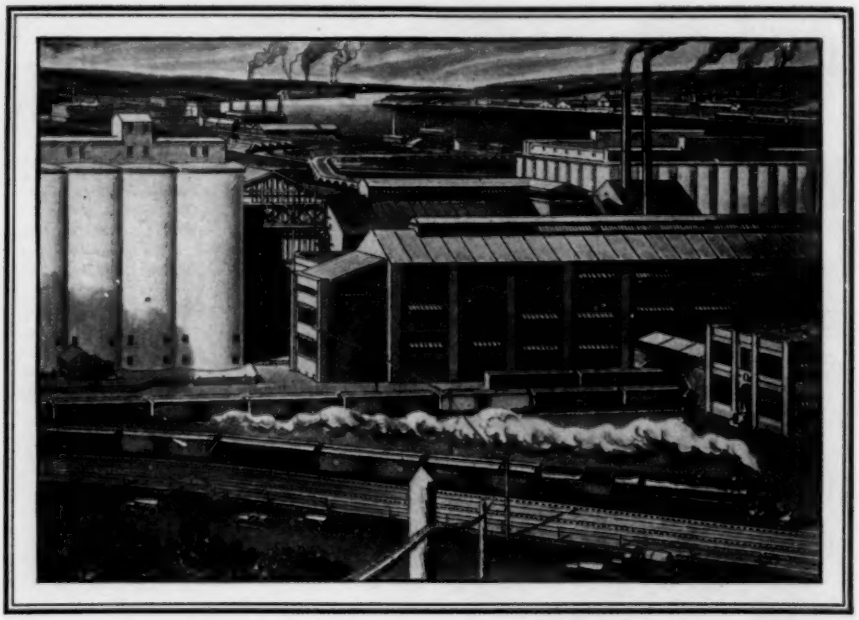

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THE DEVITRIFICATION OF SODA-LIME-SILICA GLASSES[1]

By George W. Morey

ABSTRACT

The isotherms and boundary curves in that portion of the ternary system Na_2O-SiO_2–CaO·SiO_2–SiO_2 of direct application to glass technology, namely, from 64 to 78% SiO_2, 0 to 20% CaO, including the whole of the field of the compound Na_2O·$3CaO$·$6SiO_2$, and portions of the adjoining fields of Na_2O·$2SiO_2$, Na_2O·$2CaO$·$3SiO_2$, CaO·SiO_2, tridymite, and quartz, have been determined with greater precision than in a previous study[2] by greatly increasing the number of mixtures studied, and thereby decreasing the interpolation necessary in the interpretation. An extended discussion is given of the devitrification of glass, in which it is shown that the liquidus temperature is the only datum point which is solely a function of glass composition, and is unaffected by the past history of the glass or by fortuitous circumstances at the time devitrification is taking place. At the liquidus the first trace of crystalline phase is in equilibrium with the glass; above the liquidus the glass will dissolve any such crystals which may have been formed at some previous time, but new crystals cannot form; while only below the liquidus is there a tendency for crystals to separate. The driving force causing this reaction is derived from the difference in free energy between the unstable glass and the stable aggregation of crystalline phases, and this force is opposed by a resistance of the nature of a viscosity. The dissociation in the liquid phase of the compounds which separate on devitrification diminishes the rate at which the devitrification equilibrium is reached, and increasing the complexity of the glass will have a similar effect. The excess in surface energy at the interface glass-crystal may have an influence at the instant of formation of the first infinitesimal crystal, but after the crystal has grown to a dimension appreciably greater than the sphere of molecular action the excess energy at this interface ceases to be of importance. The only surface tension measurements which have been made on glass refer to the interface glass-air, and the excess energy at this interface has no necessary correlation with the devitrification process.

Introduction

Glasses are undercooled liquids, and that property of glass which makes possible its manufacture and working, namely, the property of remaining in the noncrystallized condition while passing through the temperature range immediately below its freezing point, and persisting in that condition indefinitely at ordinary temperature, is the most important and characteristic property of glass. It would be natural to expect that a property so vital to the glass industry would long ago have been extensively studied and placed on a secure scientific basis, but such is not the case. Until the fundamental work of Morey and Bowen,[2] it was not even known what were the compositions and properties of the compounds which are formed by the devitrification of the common soda-lime glasses, and there had been no attempt made to determine the equilibrium relations between crystalline and liquid phases. The work of Morey and Bowen included the entire system Na_2O·SiO_2–CaO·SiO_2–SiO_2, and special attention was not given to the region

[1] Received July 16, 1930.

[2] G. W. Morey and N. L. Bowen, *Jour. Soc. Glass Tech.*, 9, 226 (1925).

of direct interest in glass technology. Since that time several supplementary studies have appeared, most of which have dealt with the rate of devitrification of commercial glasses, but some of which have points of contact with the above fundamental work. In view of the interest aroused in this subject since the appearance of the paper by Morey and Bowen, it has been deemed worth while to multiply greatly the number of mixtures studied within the glass field, and by that means to determine more precisely the temperature of primary crystallization within the composition

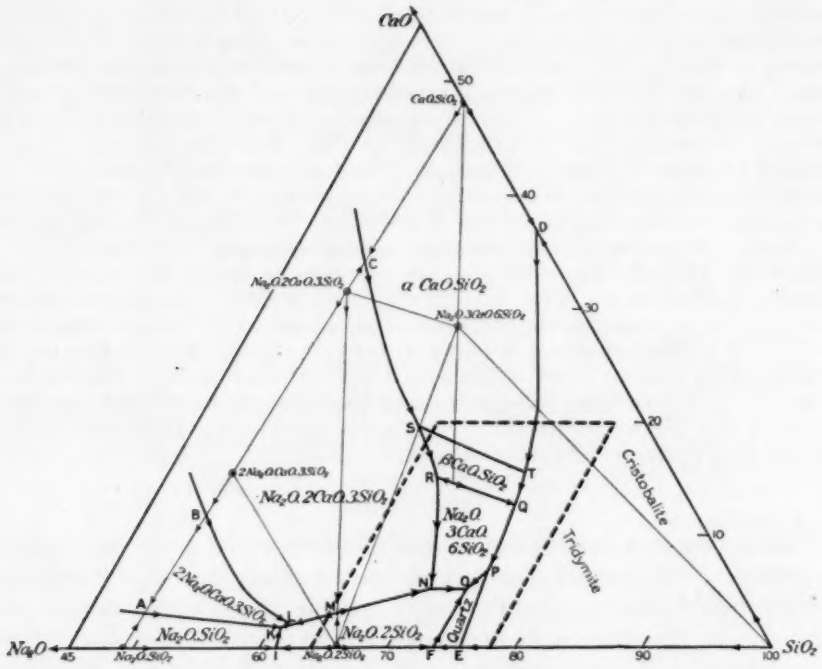

FIG. 1.—The ternary diagram Na_2O·SiO_2–CaO_2·SiO_2–SiO_2 of Morey and Bowen, showing by the heavy broken lines the composition limits of the present study.

field of importance to the glass industry. The composition range included in this new work is that from 62 to 78% SiO_2, 0 to 20% CaO, and this region is now represented by 87 glasses, instead of 20 in the original work. While the positions of the boundary curves and invariant points have been altered slightly, the alterations all have been within the limit previously set.

General Discussion

The work described in this and the several previous papers on the same

general subject[3] has dealt with the temperatures at which equilibrium takes place between glasses of various compositions and the first trace of crystalline phase to separate. This temperature is of paramount importance in any discussion dealing with the devitrification of glass. It has a definite theoretical significance, and it can with assurance be regarded as a function solely of the composition, neither of which characteristics is shared by measurements of rates of devitrification. Above this temperature, not only is the separation of crystals impossible, but also the solution of crystals in liquid takes place with absorption of energy. Below the liquidus, however, the separation of crystals takes place with evolution of energy; and in both cases the energy difference between devitrified glass and nondevitrified glass must be the source of the force causing the separation or solution of crystals. The amount of this difference will increase as the temperature is lowered from the liquidus; the rate at which this difference increases may diminish at comparatively low temperatures, it may be discontinuously, but under all conditions the transition from glassy to crystalline state will set free energy, and the glass is unstable with respect to a crystalline mixture of the same gross composition.

In considering the devitrification of glass, it is well to bear in mind that the chemistry of silicates differs not in kind but only in degree from that of the more usual compounds. Those particular compositions of matter which have been hit on for glasses have the common characteristic that they exhibit a great reluctance to pass from the liquid to the crystalline condition even under the most favorable circumstances, a characteristic possessed in a less or even a greater degree by many substances wholly unsuitable for use as glass. Many organic substances fall in this category, of which glucose solutions may be taken as an example. Some complex sulphate solutions may be obtained in a glassy form; As_2O_3 and Sb_2O_3 can both be obtained as glass, as can some of their compounds; phosphates are well known as glass formers, and indeed, the so-called meta- and pyrophosphoric acids probably are only known in the glassy condition; and the oxide B_2O_3 has never yet been obtained in the crystalline condition. Among silicates, glasses of the composition of the minerals albite and orthoclase are far more resistant toward crystallization than any commercial glasses. The phenomenon of undercooling is a usual observation with molten salts, and the glasses of commerce represent mixtures in which not only is this property of undercooling to form glasses strongly marked, but in addition the resulting glasses possess other properties which make them useful. The process of devitrification is merely the separation of

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[3] (*a*) G. W. Morey and N. L. Bowen, *Jour. Phys. Chem.*, **28**, 1167 (1924); *Jour. Soc. Glass Tech.*, **9**, 226 (1925). (*b*) F. C. Kracek, G. W. Morey, and N. L. Bowen, *Jour. Phys. Chem.*, **33**, 1857 (1929).

crystals from a melt, which cannot take place above the freezing point, but below the freezing point takes place with evolution of heat.

It is usual to discuss the devitrification of glass from the point of view of the freezing of a molten solid, but it can equally well be considered from the point of view of solubility. Fundamentally, the distinction is only one of terminology, for there is no essential difference between the processes of solution and fusion, and a melting point curve is also a solubility curve. There are some factors, however, which make worth while such a discussion. First of all, we come at once to the question of what is solvent and what solute, and the answer is at once evident when we consider the analogy with aqueous solutions. The terms in their technical sense were coined to describe the relation of the components when one is present in preponderant amount, and they become meaningless when the components are present in essentially equal quantities. Water is solvent in a 1% aqueous solution of potassium nitrate; equally logically, potassium nitrate is solvent when the proportions of water-potassium nitrate become 1:100; but to seek to apply these merely descriptive terms more closely, to attempt to fix the point at which water ceases to become solvent and becomes solute, is to attempt that which is inherently impossible. Similarly, to state what is solvent in a glass is not possible. All the components are in mutual solution, and silica is no more to be regarded as solvent than is CaO or Na_2O. Equally absurd is to attempt to pick out some particular compound, such as $Na_2O \cdot 2SiO_2$, and regard it as solvent. The fact that certain definite compounds separate from glass on crystallizing does not necessarily indicate that these compounds comprise the glass itself. Whatever we may mean by compounds in the liquid phase (and in a liquid such as glass to give such a phrase an exact meaning requires careful specification of conditions and assumptions), it is certainly true that the compound which separates is that whose solubility limit has been reached; and even though it exists in but small proportion in the liquid at the freezing point it alone will crystallize. Other compounds may be present in far larger proportion, but the separation of the insoluble compound will cause its concentration to diminish, and other molecular groupings will rearrange themselves to preserve the equilibrium in the homogeneous liquid. We know nothing about the constitution of such liquids, except that most of the compounds that separate on crystallization are highly dissociated in the liquid state. When a glass is above its liquidus temperature it is not saturated with respect to any crystalline phase which may separate at some lower temperature; and addition of a small amount of such a phase will result in its solution. On cooling to the liquidus, the glass becomes saturated with respect to the primary phase; on further cooling this phase separates, and the composition of the liquid changes, until at the boundary temperature it becomes saturated with respect to a second crystalline phase. The

solvent power of a particular glass, for example, for silica, is dependent on the composition of the glass and on the temperature; at a low temperature it may be saturated with respect to quartz, while at a higher temperature it will dissolve twice its own weight of silica before saturation; the "solubility" of silica in a glass requires specification of temperature and glass composition, and is only another way of expressing the results embodied in a melting point diagram. To consider any particular compound or combination of compounds as solvent in such a system not only is not justifiable, but also serves no useful purpose either in clarifying our ideas or in more rigorous theoretical treatment.

The equilibrium relationships between crystalline phases and liquid are wholly determined by composition and temperature, and when these are known the system is completely determined. Below the liquidus, the uncrystallized condition is unstable, but to transform it into the stable mixture of glass and crystal may be difficult. It is not known what are the factors which determine the velocity with which the unstable glass becomes transformed into the heterogeneous aggregate which is stable at the temperature in question. The difference in energy content, more exactly, the difference in the value of the zeta function defined by Gibbs[4] is the source

$$\zeta = \epsilon - t\eta + pv$$

of the driving force of the reaction. The identification of the various opposing resistances which prevent the immediate attainment of the equilibrium condition, and the assigning to each of these its appropriate weight, is not possible with our present knowledge of the processes operative in solutions, but it seems probable that viscosity plays an important, perhaps a dominant, rôle. This is certainly the case in such mixtures as those in this system, near the boundary between the fields of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ and tridymite, where the time required to redissolve tridymite crystals is many times greater than that required to form them. By the processes of devitrification pure silica has been concentrated in crystalline form, and these crystals are several hundreds of degrees below their melting point. They can be melted only by the solvent action of the rest of the glass. When they begin to dissolve, the contact layer becomes a highly siliceous glass, far more viscous than was the original glass; and for solution to be complete at the liquidus the homogeneity of the liquid must be completely restored by diffusion. a process whose rate is chiefly determined by the viscosity, and is oftentimes very slow. Similarly, crystallization requires molecular movement, the rate of which under constant force will be proportional to the viscosity. Since both the driving force and the opposing resistance increase with decreasing temperature, and the force is zero at the liquidus, it necessarily follows that there will be an optimum temperature

[4] "The Scientific Papers of J. Willard Gibbs," Vol. 1, p. 87, eq. 91.

for crystallization. At the liquidus, there is no tendency for crystals to separate; at some lower temperature the glass is too viscous to crystallize in a convenient time; at some intermediate temperature conditions will be most favorable for crystallization, and this optimum temperature usually will be not much below the melting point. But there is no especial theoretical significance to this optimum temperature. Rather it represents merely the temperature at which the interplay of the various forces and resistances, some of which may be unknown, and none of which is capable of evaluation, produce the best conditions for crystallization.

The lower limit of temperature at which crystals can be produced is likewise a wholly arbitrary temperature. It is certainly a function of the duration of the exposure to the temperature in question, and it probably also is a function of other factors not considered at present, and the influence of which is not assignable with our present knowledge of the constitution of solutions, and the mechanism of the process which takes place when a crystalline phase separates from a solution. Guertler[5] heated $Na_2O{\cdot}SiO_2$ glass at rates ranging from 7 to 300° per minute, and found that crystallization began at a fairly constant temperature, from 530 to 570°. But it is easy to crystallize $Na_2O{\cdot}SiO_2$ glass at a much lower temperature by holding for a longer time, and the temperature given by Guertler cannot be considered as a lower limit, as has been assumed to be the case.

While we have no exact information as to the nature, composition, and persistence of the molecular aggregations in a glass at its liquidus temperature, the fact that many of the compounds found on crystallizing the glass are highly dissociated, and hence for their formation require a considerable diffusion of matter, must be an important factor. This is especially true of the potash glasses, the study of which has just been published;[6] and probably has an important bearing on the circumstance that addition of small amounts of many diverse substances improves the stability of many glasses toward devitrification. It is not probable that the surface energy plays an important rôle in the devitrification process; and whatever rôle it does play is not determined by the quantity usually measured, the surface tension at the interface glass-air, but rather that at the interface between glass and crystal at the temperature in question, a quantity which has never been measured. This quantity will affect the amount of undercooling necessary to supply the energy to form the new surface of an infinitesimally small crystalline nucleus,[7] but once such a nucleus is formed the importance of the surface energy will not be significant.

It is frequently stated that glass devitrifies more readily on the surface, and that when devitrification takes place the initial growth takes place

[5] W. Guertler, *Z. anorg. Chem.*, **40**, 268 (1904).

[6] Morey, Kracek, and Bowen, *Jour. Soc. Glass Tech.*, **14**, 149 (1930).

[7] See Gibbs, *op. cit.*, p. 314.

from the surface. This probably is true under the conditions of experiment to which the observations relate, but it is not true under the conditions described in this paper. During the course of these experiments special care has been taken to observe the manner of growth of the crystals, and in no case have the crystals grown from the surface, and in no case have there been observed crystals growing from the surface of discontinuity of bubbles. Many cases have been seen in which the grains of the powdered charge have fused together without giving opportunity for the bubbles of gas to free themselves, and in no case have the crystals grown from these bubbles, or in any evident relation to them. It appears that the explanation of the effect observed by others must be sought in some cause other than the effect of the surface itself. In the case of material which has been fire polished, a difference in surface condition, caused by loss of alkali or boric oxide; or the evident fact that the surface reaches the optimum temperature for crystallization before the interior mass, may be the explanation of the observed effect. When a fresh surface of glass is formed, the instantaneous value of the surface tension will be that of material of composition uniform with the glass in mass; but, since the energy of a complex system is a function not only of temperature and surface but also of composition, there will begin at once a concentration at the surface of those components whose influence is to lower the surface energy. Whether the surface in this altered state will have a lower or higher liquidus temperature than in the unaltered condition it is not possible to state in general, because this is determined entirely by the specific properties of the particular piece of glass, but in any case there is no parallelism between this effect and the surface tension. It has also been stated that the excess energy inherent in the surface will cause crystallization to take place more readily than in the interior of the mass, because of a consequent greater mobility of the atoms forming the surface. This reasoning is fallacious. The excess energy is potential, not kinetic. Moreover, if we make that assumption in regard to glass which has been experimentally demonstrated in the case of numerous other liquids, namely, that the surface molecules or molecular groupings are oriented, and in general in such a manner that the long axis of such groupings is normal to the surface, it is probable that those units of structure comprising the surface are subject to a constraint which limits their movements, and may even diminish their degree of freedom. To describe the devitrification of glass as a surface phenomenon is misleading.

Preparation of Materials

The only difficulty encountered in making the glasses within the composition range covered by this paper is that of mechanical loss of CaO or SiO_2, owing to rapid decomposition of Na_2CO_3. As stated in previous papers, this is easily overcome by carrying out the initial decomposition at

such a temperature that the mass merely sinters, enabling the CO_2 to escape from the porous mass. To accomplish this it sufficed to put the platinum crucible containing the powdered and mixed ingredients into a cold furnace which would require some hours, usually over night, to come to about 1000°, after which it could be quickly heated to 1300 to 1400°, at which temperature most of the glasses were fined.

After the initial heating, the glasses were powdered to pass 66-mesh bolting cloth, then re-melted, and this process of powdering and re-melting continued until no inhomogeneity could be detected in the powdered glass when examined under the microscope, using an immersion liquid matching it in refractive index. By this method a variation in refractive index amounting to 1 to 2 units in the third decimal place can be detected readily. After this the final heating was made in a clean platinum crucible. The behavior of the glasses when heated near the liquidus furnishes a sensitive criterion of homogeneity. If the material is not uniform, crystals are irregularly distributed, some grains having many, while most of the grains have none.

The composition of the glasses was established by careful control throughout the melting process. The platinum crucible in which the meltings were made was weighed before and after each heating and each pulverizing operation, so that, knowing the amounts of the nonvolatile oxides, CaO and SiO_2, the exact composition of the glass could be calculated. The sources of error are (1) the variation in weight of the platinum crucible during the melting operation, either by loss of platinum, an unimportant item, or by material sticking to the outside of the crucible, a source of error difficult to avoid at high temperatures where the best of refractories tends to stick to platinum. This was finally obviated by resting the crucible on a flat polished plate cut from a corundum crystal. The same crucible was used for many glasses, and the record shows that the loss in weight was less than 1 mg. per glass made, which includes three or four meltings, and a cleansing by fusion with Na_2CO_3. (2) The material lost during the powdering operation may not be of exactly the same composition as the melt as a whole. The loss was rarely 0.1 g., and usually was one-half to one-third this, hence, to make a sensible error the portion lost would have to be grossly inhomogeneous; but the glass at the first pulverization was one which already had reached some degree of homogeneity during fining. (3) The material lost on heating might not be Na_2O alone, but also some CaO or SiO_2. This is not regarded as probable; only on the first heating is there danger of mechanical loss, and especial care was taken to avoid loss during this period. (4) Usually a factor was used to convert $CaCO_3$ to CaO, and the CaO content is, of course, dependent on this factor. It was usually determined by heating the $CaCO_3$ for some melt high in CaO until a constant weight was obtained, and this factor was frequently checked.

The SiO_2 was dried at 500°, and all ingredients were stored in a desiccator over KOH. None of these errors, however, is of great moment, and it is believed that the compositions of the glasses made in this way are better known than would be possible by chemical analysis.

To make more clear the exact procedure, the log of a typical melting is reproduced in Table I; the glass is No. 73 of Tables II and III.

TABLE I

LOG OF A TYPICAL GLASS MELTING

Weight platinum crucible	15.2885		
$+Na_2CO_3$	16.9999	1.7114	
$+CaCO_3$	18.4721	1.4722	
$+SiO_2$	21.8067	3.3346	
After fining	20.2966	5.0081	
After pulverizing	20.2098		0.0868
After 2nd fining	20.2055		
After 2nd pulverizing	20.1215		0.0840
After 3rd fining	20.1212	4.8317	

The pulverized glass was now transferred to a clean crucible, and fined, during which fining the melt lost 1.2 mg. The final composition is then that calculated in Table II.

In cases in which the synthetic procedure was not followed, or in which for some reason it was not carried out, the glasses were analyzed, following the procedure recommended by Hillebrand[8] and Lundell for materials which can be decomposed by fusion with Na_2CO_3. Some glasses low in SiO_2 were analyzed by decomposition with HCl, making separate determinations of each constituent. SiO_2 always was separated by two evaporations with intervening filtration. CaO was separated as oxalate, making a double precipitation. Fe_2O_3 and Al_2O_3 were not determined separately, and hence would largely appear as impurities in the CaO. Since all meltings were in platinum, the only impurities were those introduced in the original ingredients, which were of a high degree of purity. The SiO_2 was a good grade of quartz, which gave but 0.07% residue after evaporation with HF + H_2SO_4. The $CaCO_3$ was an unusually pure preparation, an analysis of which by my colleague, Dr. E. G. Zies, gave, in percentages, SiO_2, 0.002, $Fe_2O_3 + Al_2O_3$, 0.006, MgO, 0.003. Thus every mixture represented known proportions of the three components, Na_2O, CaO, and SiO_2, in a homogeneous glass practically free from impurity. The compositions of the glasses are given in Table II; those compositions determined by analysis are indicated by the percentage composition of one of the components being enclosed in parentheses, to denote that it was obtained by difference.

Quenching Procedure and Identification of Phases

The method of studying the phase equilibrium was that of quenching, so extensively used in this Laboratory since its application to the study of

[8] W. F. Hillebrand and G. E. F. Lundell, Applied Inorganic Analysis, New York, 1929.

phase equilibria by Shepherd and Rankin.[9] As has often been explained, a small charge of the powdered material, about 10 mg. wrapped in platinum or gold foil, 0.01 mm. thick, is held at constant temperature long enough for equilibrium to be reached, cooled at such a rate as to freeze that equilibrium, and examined with the petrographic microscope. By varying the temperature the limits between which the charge is either all glass or partially crystalline can be fixed as closely as desired; in Table III are shown the limits between which the temperature was fixed in each case. The length of time required for equilibrium to be reached varied widely, and it is necessary to consider each mixture separately. In general, mixtures whose liquidus is above 1200° crystallize so readily, whatever the crystalline phase, that 15 minutes is sufficient for equilibrium, and in such cases there is no necessity for approaching the equilibrium from both directions. Other mixtures are difficult to crystallize, and require hours or days of heating at the most favorable temperature. In such cases it is advisable to put two charges into the furnace side by side, one of which is glass, the other, glass which has been partially devitrified. Then if both preparations come to the same condition it is certain that equilibrium has been recached; if not, the heat treatment should be lengthened until equilibrium is reached. With mixtures near the ternary eutectic, or along the boundary between $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ and quartz or tridymite, it is necessary to start with a very fine-grained crystallization, otherwise an undue time will be required to dissolve the crystals at the liquidus. It was also found that the compound $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ requires several hours to decompose into $CaO{\cdot}SiO_2$ and glass, even 10° above its true decomposition temperature.

The experimental methods used have been given in detail, because there has been some failure to comprehend the fact that in such studies we are dealing with equilibrium relations. The liquidus temperatures given are not affected by the many factors which affect the rate of crystallization, an entirely different matter. They are independent of the thermal history of the glass, and of the presence of bubbles or other possible nuclei. Moreover, the initial glasses were, as explained above, homogeneous. The several fining operations, with intermediate pulverizing, which have been described above, were made because such extreme care is necessary to obtain a glass homogeneous enough to give satisfactory results in the liquidus determinations. Of commercial glasses, only optical glass of first quality, which is free from striae when examined in all directions, is homogeneous enough to meet the requirements in this work. Ordinary plate or bottle glass is grossly inhomogeneous, as shown by the presence of cords or striae, and such inhomogeneity is shown at once on thermal treatment by an irregular distribution of crystals when held just below the liquidus.

Temperature measurements were made with a platinum–platinum +

[9] E. S. Shepherd and G. A. Rankin, *Amer. Jour. Sci.*, **28**, 308 (1909).

10% rhodium thermocouple, the junction of which was placed within one or two millimeters of the quenching change, located in that portion of a platinum resistance furnace where the temperature gradient was a minimum. The e.m.f. of the thermocouple was determined with the aid of a White potentiometer, made by Leeds and Northrup; and Adams' Tables[10] were used in converting e.m.f. to degrees Centigrade, with the aid of a deviation curve. The thermocouples were calibrated at the melting points of anorthite,[11] 1550.0°; diopside,[11] 1391°; Li_2SiO_3,[11] 1201°; gold,[11] 1062.6°; Na_2SO_4,[12] 884.7°; NaCl,[12] 800.4°, and frequently checked during the course of the work.

TABLE II

COMPOSITIONS AND LIQUIDUS TEMPERATURE OF THE GLASSES STUDIED

No.	Composition			Temp., °C	Phase
	Na_2O	CaO	SiO_2		
1	16.98	5.01	78.01	1140	Tridymite
2	12.0	10.0	78.0	1268	"
3	14.93	8.01	77.06	1155	"
4	12.85	11.03	76.12	1146	"
5	8.90	14.99	76.11	1325	"
6	18.89	5.01	76.10	1000	"
7	6.18	17.96	75.86	1438	Cristobalite
8	(18.64)	5.76	75.61	973	Tridymite
9	17.25	7.54	75.21	997	"
10	(15.30)	9.66	75.04	1065	"
11	17.5	7.5	75.0	980	"
12	15.04	9.98	74.98	1067	"
13	15.28	10.03	74.69	1039	"
14	19.56	6.03	74.41	848	"
15	15.95	9.66	74.39	985	"
16	12.82	12.98	74.20	1107	"
17	14.48	7.34	74.15	881	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
18	(20.73)	5.12	74.15	810	Quartz
19	21.84	4.01	74.15	748	$Na_2O{\cdot}2SiO_2$
20	13.88	12.02	74.10	1058	Tridymite
21	15.04	11.03	73.93	994	"
				980	" + $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
22	16.17	9.98	73.85	974	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
23	12.95	13.44	(73.61)	1078	Tridymite
24	7.32	19.04	73.64	1328	Tridymite
25	16.42	10.02	73.56	974	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
26	(23.48)	3.07	73.45	758	$Na_2O{\cdot}2SiO_2$
27	13.38	13.23	73.39	1067	$CaO{\cdot}SiO_2$
28	21.71	5.00	73.29	746	Quartz
29	13.81	13.02	73.17	1042	$CaO{\cdot}SiO_2$
30	11.22	15.66	73.12	1147	"
31	17.91	9.01	73.08	941	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
32	20.99	6.00	73.01	797	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
33	19.50	7.50	73.00	890	"
34	8.1	19.0	72.9	1251	Tridymite
				1240	$CaO{\cdot}SiO_2$ + tridymite

[10] L. H. Adams, *Jour. Amer. Chem. Soc.*, **36**, 65 (1918); International Critical Tables, Vol. 1, p. 57 (1926).

[11] A. L. Day and R. B. Sosman, "High Temperature Gas Thermometry," Carnegie Inst. Washington, *Publ.*, No. 157 (1911).

[12] H. S. Roberts, *Phys. Rev.*, **23**, 386 (1924).

TABLE II (*concluded*)

No.	Composition			Temp., °C	Phase
	Na_2O	CaO	SiO_2		
35	13.35	13.85	72.80	1076	$CaO \cdot SiO_2$
36	11.93	15.31	72.76	1106	"
37	11.82	16.03	72.15	1139	"
38	22.85	5.01	72.14	737	$Na_2O \cdot 2SiO_2$
39	8.92	19.02	72.06	1235	$CaO \cdot SiO_2$
40	18.52	10.10	71.38	968	$Na_2O \cdot 3CaO \cdot 6SiO_2$
41	14.31	14.37	71.32	1078	$CaO \cdot SiO_2$
42	10.91	18.02	71.07	1188	"
43	(21.35)	7.54	71.11	878	$Na_2O \cdot 3CaO \cdot 6SiO_2$
44	17.09	12.07	70.84	1006	"
45	24.02	5.32	70.66	780	"
46	(23.47)	6.06	70.47	826	"
47	15.68	14.04	70.28	1051	"
48	21.71	8.03	70.26	909	"
49	23.26	6.52	70.22	845	"
50	24.86	4.94	70.20	766	$Na_2O \cdot 2SiO_2$
51	14.83	15.00	70.17	1084	$CaO \cdot SiO_2$
52	15.91	14.08	70.01	1051	$Na_2O \cdot 3CaO \cdot 6SiO_2$
53	24.71	5.31	69.98	788	"
				781	$Na_2O \cdot 3CaO \cdot 6SiO_2 + Na_2O \cdot 2CaO \cdot 3SiO_2$
54	15.78	14.52	69.70	1066	$CaO \cdot SiO_2$
55	25.79	5.01	69.20	801	$Na_2O \cdot 2CaO \cdot 3SiO_2$
56	19.81	11.00	69.19	985	$Na_2O \cdot 3CaO \cdot 6SiO_2$
57	15.89	15.00	69.11	1074	$CaO \cdot SiO_2$
58	23.22	8.02	68.76	892	$Na_2O \cdot 3CaO \cdot 6SiO_2$
				890	$Na_2O \cdot 3CaO \cdot 6SiO_2 + Na_2O \cdot 2CaO \cdot 3SiO_2$
59	20.90	10.84	68.26	983	$Na_2O \cdot 3CaO \cdot 6SiO_2$
60	13.83	18.04	68.13	1157	$CaO \cdot SiO_2$
61	24.95	7.00	68.05	889	$Na_2O \cdot 2CaO \cdot 3SiO_2$
62	16.45	15.59	67.96	1086	$CaO \cdot SiO_2$
63	22.10	10.14	67.76	975	$Na_2O \cdot 2CaO \cdot 3SiO_2$
				974	$Na_2O \cdot 2CaO \cdot 3SiO_2 + Na_2O \cdot 3CaO \cdot 6SiO_2$
64	18.36	13.98	67.66	1045	$Na_2O \cdot 3CaO \cdot 6SiO_2$
65	16.48	16.07	67.45	1092	$CaO \cdot SiO_2$
66	(28.20)	4.45	67.35	850	$Na_2O \cdot 2CaO \cdot 3SiO_2$
67	19.64	13.03	67.33	1017	$Na_2O \cdot 3CaO \cdot 6SiO_2$
68	17.90	14.78	67.32	1057	"
69	21.01	11.98	67.01	997	"
				985	$Na_2O \cdot 3CaO \cdot 6SiO_2 + Na_2O \cdot 2CaO \cdot 3SiO_2$
70	17.45	15.57	66.98	1078	$Na_2O \cdot 3CaO \cdot 6SiO_2$
71	17.12	16.00	66.88	1088	$CaO \cdot SiO_2$
72	(18.48)	15.47	66.05	1062	$Na_2O \cdot 3CaO \cdot 6SiO_2$
73	16.87	16.49	66.65	1102	$CaO \cdot SiO_2$
74	23.45	10.07	66.48	992	$Na_2O \cdot 2CaO \cdot 3SiO_2$
75	18.69	14.91	66.40	1059	$Na_2O \cdot 3CaO \cdot 6SiO_2$
76	17.46	16.17	66.37	1085	$CaO \cdot SiO_2$
77	17.80	16.04	66.16	1078	"
78	18.95	15.06	65.99	1063	$Na_2O \cdot 2CaO \cdot 3SiO_2$
				1054	$Na_2O \cdot 2CaO \cdot 3SiO_2 + Na_2O \cdot 3CaO \cdot 6SiO_2$
79	19.25	14.98	65.77	1063	$Na_2O \cdot 2CaO \cdot 3SiO_2$
				1058	$Na_2O \cdot 2CaO \cdot 3SiO_2 + Na_2O \cdot 3CaO \cdot 6SiO_2$
80	(18.66)	15.94	65.37	1082	$Na_2O \cdot 2CaO \cdot 3SiO_2$
81	(19.22)	15.46	65.32	1075	"
82	(21.80)	13.09	65.11	1060	"
83	(30.87)	4.27	64.86	907	"
84	32.82	2.40	64.78	846	$Na_2O \cdot 2SiO_2$
85	32.40	3.02	64.55	862	$Na_2O \cdot 2CaO \cdot 3SiO_2$
				844	$Na_2O \cdot 2CaO \cdot 3SiO_2 + Na_2O \cdot 2SiO_2$
86	17.70	17.96	64.54	1135	$CaO \cdot SiO_2$
87	(27.20)	8.33	64.47	1014	$Na_2O \cdot 2CaO \cdot 3SiO_2$

TABLE III

QUENCHING DATA FOR THE GLASSES OF TABLE II

No.	Initial condition	Temp., °C	Time	Final condition
			Primary phase tridymite	
1	G	1139	8 h	Glass; tridymite
	X	1141	16 h	Glass
2	G	1265	15 m	Glass; tridymite
	X	1268	15 m	Glass
3	G	1153	1 h	Glass; tridymite
	X	1156	6 h	Glass
4	G	1144	4 h	Glass; very rare tridymite
	X	1149	12 h	Glass
5	G	1324	30 m	Glass; rare tridymite
	X	1320	30 m	Glass
6	G	990	60 m	Glass; tridymite
	G	997	90 m	Glass; rare tiny tridymite
	G	1002	16 h	Glass
7	G	1475	10 m	Glass; cristobalite
	G	1480	10 m	Glass
8	G	970	20 h	Glass; rare tridymite
	X	974	6 h	Glass
9	G	995	2 h	Glass; tridymite
10	G	1049	1 h	Glass; tridymite
	X	1063	1 h	Glass; very rare tridymite
	X	1067	1 h	Glass
11	G	978	1 h	Glass; tridymite
	X	981	1 h	Glass
12	G	1065	24 h	Glass; tridymite
	G	1068	24 h	Glass
13	G	1037	3 h	Glass; tridymite
	X	1040	12 h	Glass
15	G	983	16 h	Glass; well-formed, but very thin, tridymite plates
	X	986	16 h	Glass
16	G	1100	6 h	Glass; tridymite
	X	1106	24 h	Glass; rare tridymite
	X	1107	6 h	Glass
20	G	1055	8 h	Glass; rare tridymite
	X	1060	20 h	Glass
21	G	975	8 h	Glass; tridymite; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	988	16 h	Glass; tridymite
	G	992	8 h	Glass; tridymite
	X	995	6 h	Glass; rare tridymite
	X	995	16 h	Glass
23	G	1070	1 h	Glass; tridymite
	X	1076	3 h	Glass; very rare tridymite
	X	1079	1 h	Glass
24	G	1327	10 m	Glass; rare tridymite
	G	1329	20 m	Glass
34	G	1238	30 m	Glass; $CaO{\cdot}SiO_2$ + tridymite
	X	1242	50 m	Glass; tridymite only
	G	1249	15 m	Glass; very rare tridymite
	G	1252	15 m	Glass
			Primary phase quartz	
14	G	830	10 h	Glass; good quartz; tridymite
	X	845	22 h	Glass; few excellent quartz
	X	850	16 h	Glass
18	G	792	17 h	Glass; quartz; tridymite; cristobalite
	X	808	18 h	Glass; quartz
	X	811	36 h	Glass
28	G	741	2 d	Glass; quartz
	X	750	6 d	Glass

TABLE III (*continued*)

No.	Initial condition	Temp., °C	Time	Final condition
				Primary phase $CaO{\cdot}SiO_2$
27	G	1063	1 h	Glass; $CaO{\cdot}SiO_2$
	X	1067	3 h	Glass
29	G	1030	2 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	1037	12 h	Glass; $CaO{\cdot}SiO_2$
	X	1041	8 h	Glass; $CaO{\cdot}SiO_2$
	X	1043	12 h	Glass
30	G	1145	3 h	Glass; $CaO{\cdot}SiO_2$
	X	1147	1 h	Glass
35	G	1072	45 m	Glass; small amount $CaO{\cdot}SiO_2$
	X	1077	45 m	Glass
36	X	1105	20 m	Glass; $CaO{\cdot}SiO_2$
	X	1107	20 m	Glass
37	G	1138	90 m	Glass; $CaO{\cdot}SiO_2$
	X	1140	90 m	Glass
39	G	1234	1 h	Glass; $CaO{\cdot}SiO_2$
	X	1236	45 m	Glass
41	G	1069	4 h	Glass; $CaO{\cdot}SiO_2$
	X	1076	6 h	Glass; trace $CaO{\cdot}SiO_2$
	X	1080	6 h	Glass
42	G	1186	45 m	Glass; $CaO{\cdot}SiO_2$
	X	1189	45 m	Glass
51	G	1082	3 h	Glass; $CaO{\cdot}SiO_2$
	G	1086	3 h	Glass
54	G	1061	2 h	Glass; $CaO{\cdot}SiO_2$
	X	1067	2 h	Glass
57	G	1054	1 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	1071	2 h	Glass; $CaO{\cdot}SiO_2$
	X	1077	4 h	Glass
60	G	1156	1 h	Glass; $CaO{\cdot}SiO_2$
	G	1158	1 h	Glass
62	G	1083	3 h	Glass; $CaO{\cdot}SiO_2$
	X	1088	16 h	Glass
65	G	1089	1 h	Glass; $CaO{\cdot}SiO_2$
	G	1091	4 h	Glass; exceedingly rare $CaO{\cdot}SiO_2$
	X	1092	4 h	Glass
70	G	1060	30 m	Glass; $CaO{\cdot}SiO_2$
	X	1077	4 h	Glass; very rare $CaO{\cdot}SiO_2$
	X	1079	5 h	Glass
71	G	1080	3 h	Glass; numerous $CaO{\cdot}SiO_2$
	G	1087	12 h	Glass; very rare $CaO{\cdot}SiO_2$
	X	1091	2 h	Glass
73	G	1096	3 h	Glass; numerous $CaO{\cdot}SiO_2$
	X	1103	2 h	Glass
76	G	1081	1 h	Glass; $CaO{\cdot}SiO_2$
	X	1087	1 h	Glass
77	G	1076	2 h	Glass; very rare $CaO{\cdot}SiO_2$
	X	1079	3 h	Glass
81	G	1095	1 h	Glass; $CaO{\cdot}SiO_2$
	X	1099	1 h	Glass; rare $CaO{\cdot}SiO_2$
	X	1102	1 h	Glass
86	G	1108	4 h	Glass; $Na_2O{\cdot}2CaO{\cdot}3SiO_2$; $CaO{\cdot}SiO_2$
	X	1133	18 h	Glass; $CaO{\cdot}SiO_2$
	X	1136	3 h	Glass
				Primary phase $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ (1:3:6)
17	G	879	16 h	Glass; very rare 1:3:6
	X	883	3 h	Glass; still crystals
	X	883	16 h	Glass
22	X	971	22 h	Glass; rare 1:3:6
	X	974	22 h	Glass

TABLE III (*continued*)

No.	Initial condition	Temp., °C	Time	Final condition
25	G	972	18 h	Glass; rare 1:3:6
	X	977	24 h	Glass
31	G	940	16 h	Glass; few 1:3:6
	X	942	5 h	Glass
32	G	793	24 h	Glass; rare 1:3:6
	X	801	2 d	Glass
33	G	889	30 h	Glass; long large needles of 1:3:6
	X	892	22 h	Glass
40	G	963	3 h	Glass; good 1:3:6
	X	967	1 h	Glass; exceedingly rare 1:3:6
	X	968	1 h	Glass
43	G	719	17 h	Glass; 1:3:6; quartz
	G	868	17 h	Glass; 1:3:6
	G	876	16 h	Glass; rare 1:3:6
	X	879	3 h	Glass
44	G	1004	2 h	Glass; 1:3:6
	X, G	1006	20 h	Glass still glass; exceedingly small amount 1:3:6 in X
45	G	779	2 d	Glass; 1:3:6
	X	781	1 d	Glass
46	G	760	67 h	Glass; rare needles 1:3:6
	X	825	2 h	Glass; rare needles 1:3:6
	X	827	30 m	Glass
47	G	1050	2 h	Glass; very rare 1:3:6
	G	1054	11 h	Glass
48	G	908	1 d	Glass; very rare 1:3:6
	X	909	16 h	Glass
49	X	843	8 h	Glass; 1:3:6
	X	848	12 h	Glass
52	G	1048	1 h	Glass; 1:3:6
	X	1050	2 h	Glass; very rare 1:3:6
	X	1055	1 h	Glass
53	G	780	2 d	Glass; rare 1:2:3; much 1:3:6
	X	785	17 h	Glass; few 1:3:6
	X	790	6 h	Glass; rare 1:3:6
	X	790	16 h	Glass
56	G	880	4 h	Glass; little 1:3:6
	G	884	4 h	Glass; rare 1:3:6
	G	886	16 h	Glass
58	G	888	3 h	Glass; 1:2:3; 1:3:6
	X	892	18 h	Glass; 1:3:6
	X	894	16 h	Glass
59	X	983	17 h	Glass; rare 1:3:6
	X	984	4 h	Glass
64	G	1042	3 h	Glass; 1:3:6
	X	1046	6 h	Glass
67	G	1010	1½ h	Glass; much 1:3:6
	X	1016	4 h	Glass; 1:3:6
	X	1018	3 h	Glass
68	G	1056	4 h	Glass; 1:3:6
	X	1058	20 h	Glass
69	G	983	20 h	Glass; rare 1:2:3; more 1:3:6
	X	985	20 h	Glass; 1:3:6
	X	997	20 h	Glass
72	G	1058	16 h	Glass; 1:3:6
	X	1064	2 h	Glass
75	G	1058	1 h	Glass; rare 1:3:6
	X	1062	1 h	Glass
		Primary phase $Na_2O{\cdot}2CaO{\cdot}3SiO_2$ (1:2:3)		
55	G	780	16 h	Glass; much $Na_2O{\cdot}2SiO_2$; 1:2:3
	X	786	16 h	Glass; little $Na_2O{\cdot}2SiO_2$; 1:2:3

TABLE III (*concluded*)

No.	Initial condition	Temp., °C	Time	Final condition
	X	788	2 d	Glass; 1:2:3
	X	800	8 h	Glass; exceedingly rare 1:2:3
61	G	890	16 h	Glass; 1:3:6
	X	894	24 h	Glass
63	G	962	5 h	Glass; 1:2:3; 1:3:6
	X	966	5 h	Glass; 1:2:3
	X	970	1 h	Glass
66	G	722	20 h	Glass; $Na_2O{\cdot}2SiO_2$; 1:2:3
	X	818	30 m	Glass; same two cryst. phases in small amount
	X	820	20 m	Glass; 1:2:3
	X	848	20 m	Glass; rare 1:2:3
	X	852	20 m	Glass
74	G	991	17 h	Glass; rare well-formed 1:2:3
	X	993	24 h	Glass
78	G	1053	1 h	Glass; 1:2:3; 1:3:6
	X	1055	1 h	Glass; 1:2:3
	X	1062	1 h	Glass; very rare 1:2:3
	X	1064	1 h	Glass
79	G	1057	1 h	Glass; very rare 1:3:6; 1:2:3
	X	1058	1 h	Glass; 1:2:3
	G	1062	1 h	Glass; rare 1:2:3
	X	1066	1 h	Glass
80	G	1054	18 h	Glass; 1:2:3
	X	1081	20 m	Glass; exceedingly rare 1:2:3
	X	1083	20 m	Glass
81	G	1072	20 m	Glass; 1:2:3
	X	1074	20 m	Glass; rare 1:2:3
	X	1076	20 m	Glass
82	G	1044	1 h	Glass; much 1:2:3
	X	1059	1 h	Glass; rare 1:2:3
	X	1060	1 h	Glass
83	G	903	1 h	Glass; 1:2:3
	G	905	1 h	Glass; very few 1:2:3
	X	907	1 h	Glass
85	G	842	17 h	Glass; $Na_2O{\cdot}2SiO_2$; 1:2:3
	X	861	16 h	Glass; little 1:2:3
	X	863	8 h	Glass
87	G	1013	1 h	Glass; very rare 1:2:3
	X	1017	1 h	Glass

Primary phase $Na_2O{\cdot}2SiO_2$

19 It was very difficult to obtain conclusive results with this preparation. For the first crystallization it was necessary to resort to hydrothermal methods, under which conditions $Na_2O{\cdot}2SiO_2$, $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and quartz were obtained in a fine-grained intricate intergrowth, with the quartz in comparatively large grains. The disilicate disappeared completely at 750°, but the large quartz crystals would not dissolve in 3 days at 760°, although it was apparent that solution was in process. Crystallization was at last induced in the dry way, and it became probable that $Na_2O{\cdot}2SiO_2$ was the primary phase, with quartz separating as secondary phase not more than 2° lower.

26	G	717	3 d	Glass; $Na_2O{\cdot}2SiO_2$; quartz
	X	838	1 d	Glass; $Na_2O{\cdot}2SiO_2$
38	G	733	2 d	Glass; $Na_2O{\cdot}2SiO_2$
	X	750	13 h	Glass
50	X	763	2 d	Glass; many $Na_2O{\cdot}2SiO_2$
	X	767	14 h	Glass
84	G	844	3 h	Glass; $Na_2O{\cdot}2SiO_2$
	X	847	2 h	Glass; rounded $Na_2O{\cdot}2SiO_2$
	X	847	20 h	Glass

Experimental Results

The experimental results are assembled in Tables II and III, and presented graphically in several figures. Table II gives the composition of each glass, its liquidus temperature, and the composition of the primary phase. In some cases the temperature at which the secondary crystallization begins, the boundary temperature, is also given. Table III gives enough of the experimental results to substantiate Table II; in every case more quenches were made than are given in the table. Figure 1 is a reproduction of the ternary diagram of Morey and Bowen, in which is shown the stability fields of each compound, that is, the composition limits within which that compound is primary phase. The composition region included in the present study is shown by the broken lines, which take in the entire field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and portions of the adjoining fields of the compounds $Na_2O{\cdot}2SiO_2$, $Na_2O{\cdot}2CaO{\cdot}3SiO_2$, $CaO{\cdot}SiO_2$, and silica in the forms of tridymite and quartz. Figures 3, 4, and 5 give sections through the solid T-X model in several different directions.

The positions of the boundary curves and invariant points have been slightly altered by these latest measurements, but the change is too little to be noticeable in Fig. 1. They are shown in detail in the large scale diagram of Fig. 2. The composition of the ternary eutectic between $Na_2O{\cdot}2SiO_2$, $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and quartz has been changed from 5.2 to 5.0% CaO, 73.5 to 73.1% SiO_2, but the temperature has not been altered. The reaction point $Na_2O{\cdot}2SiO_2$–$Na_2O{\cdot}2CaO{\cdot}3SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$ has been changed from 5.2 to 5.0% CaO, 70.7 to 70.0% SiO_2, and the temperature has been raised from 740 to 760°. These changes are caused by the results with new glasses nearer in composition to these invariant points than any in the previous work, and they do not conflict with any of the earlier determinations.

In the preceding paper the coördinates of the invariant points at the ends of the boundary line between $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ and $CaO{\cdot}SiO_2$ were not given, and there were no determinations near this boundary. In the present paper this region was studied with especial care, and the position of the boundary curve and its intersections with the tridymite and $Na_2O{\cdot}2CaO{\cdot}3SiO_2$ fields were determined. The invariant point $Na_2O{\cdot}2CaO{\cdot}3SiO_2$–$CaO{\cdot}SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$ is at 15.1% CaO, 66.1% SiO_2, and 1060°; the invariant point $Na_2O{\cdot}3CaO{\cdot}6SiO_2$–$CaO{\cdot}SiO_2$–tridymite at 12.7% CaO, 73.7% SiO_2, and 1030°. Pure $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ decomposes into $CaO{\cdot}SiO_2$ and glass at 1060°; the pure compound melts incongruently at 1325°, but its composition lies outside of the composition limits under consideration. If a glass lies on the straight line[13] passing through the points $CaO{\cdot}SiO_2$ and $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and contains 20% CaO it will begin to

[13] The equation of this line is $z = 0.7440 - 0.4676y$, in which y = weight fraction CaO, z = weight fraction SiO_2. See G. W. Morey, *Jour. Phys. Chem.*, **34**, 1745(1930).

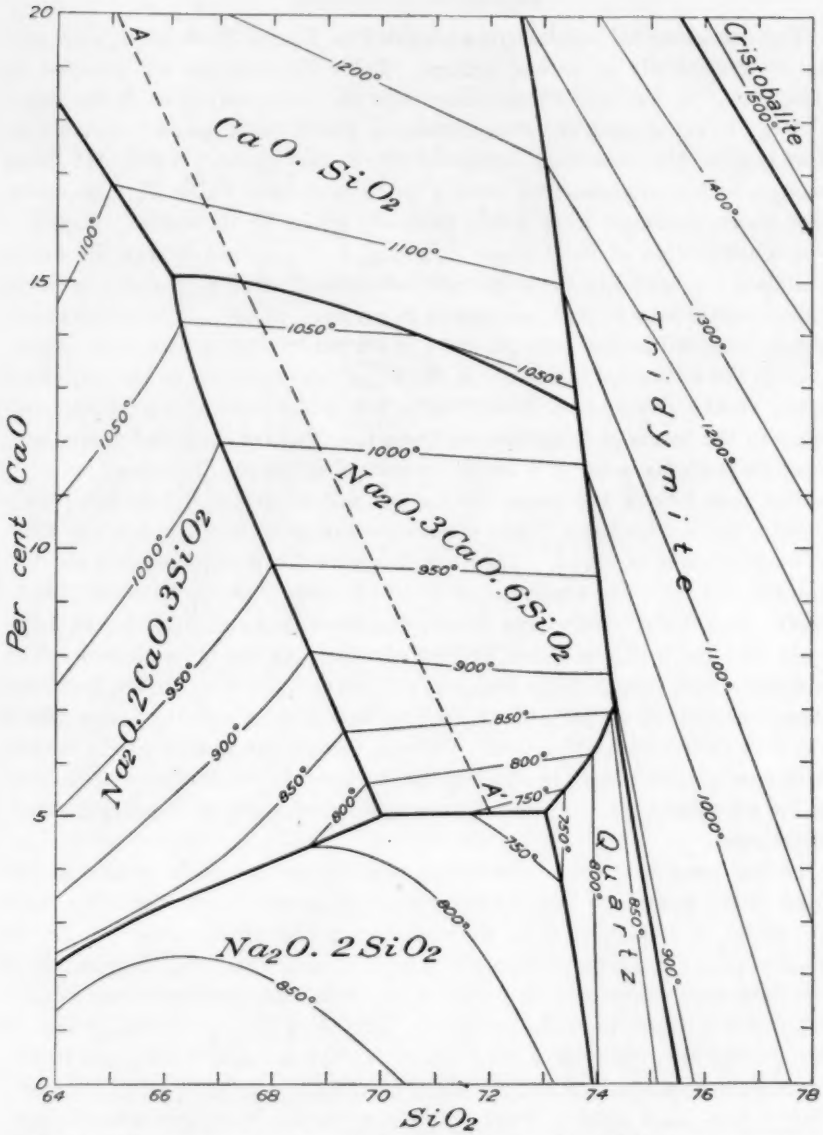

FIG. 2.—The isotherms and boundary lines in that portion of the ternary system Na_2O–CaO–SiO_2 of interest in glass technology. Weight % SiO_2 is indicated along the horizontal axis; weight % CaO along the vertical axis; weight % Na_2O is obtained by subtracting the sum of CaO and SiO_2 from 100%.

crystallize at 1190°, with separation of $CaO \cdot SiO_2$ in the form of wollastonite.[14] On further cooling, the glass will necessarily remain on this line, and will follow the temperature-composition curve of Fig. 4. Crystallization

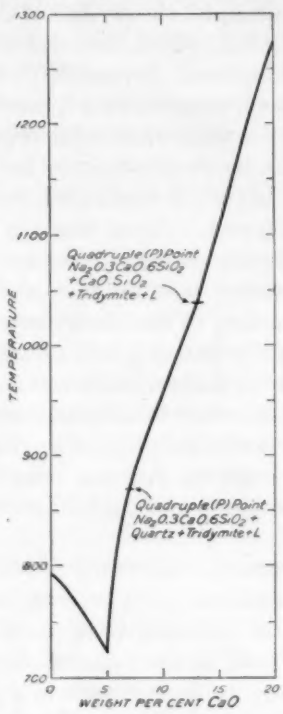

FIG. 3.—The variation of temperature with weight % CaO along the boundary between the two forms of SiO_2, quartz and tridymite, and the compounds $Na_2O \cdot 2SiO_2$, from 0% CaO to the eutectic; $Na_2O \cdot 3CaO \cdot 6SiO_2$, from the eutectic to the quadruple point $Na_2O \cdot 3CaO \cdot 6SiO_2$–tridymite–L; and $CaO \cdot SiO_2$, from the quadruple point to the side of the diagram.

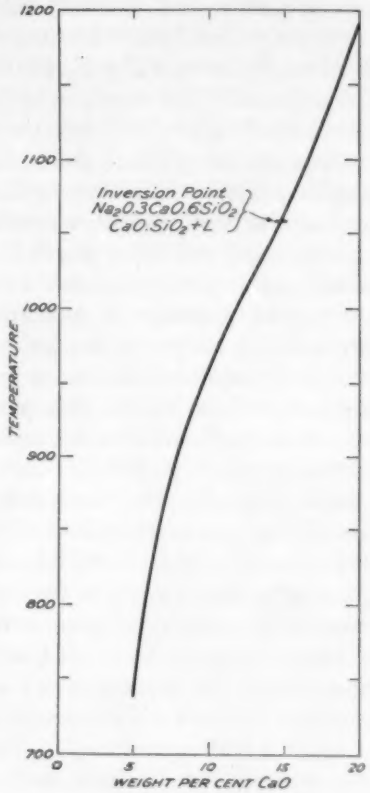

FIG. 4.—The variation of temperature with weight % CaO along the straight line passing through the composition $CaO \cdot SiO_2$ and $Na_2O \cdot 3CaO \cdot 6SiO_2$, and ending at the boundary line between the fields of $Na_2O \cdot 3CaO \cdot 6SiO_2$ and $Na_2O \cdot 2SiO_2$.

[14] In writing this paper the distinction between the two forms of $CaO \cdot SiO_2$, wollastonite and pseudo-wollastonite, stable respectively below and above 1200°, has not been made, although in the experimental work the phases were differentiated. While pseudo-wollastonite frequently appears in the stability field of wollastonite, there is no difficulty in distinguishing between the two, and no difference could be established in the liquidus temperatures.

takes place easily in this region. When the temperature has fallen to 1060°, if sufficient time is given for equilibrium to be attained, the crystals of $CaO \cdot SiO_2$ will react with the liquid to form $Na_2O \cdot 3CaO \cdot 6SiO_2$, but this transformation is slow, and ordinarily will not take place. Below 1060°, however, the stable $Na_2O \cdot 3CaO \cdot 6SiO_2$ is formed, and temperature will continue to fall along the curve of Fig. 4. On continued cooling, equilibrium requires that $Na_2O \cdot 3CaO \cdot 6SiO_2$ continue to form until the intersection of the line $CaO \cdot SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$ with the $Na_2O \cdot 3CaO \cdot 6SiO_2$–$Na_2O \cdot 2SiO_2$ boundary, where the latter phase should begin to appear. Since, however, the composition of sodium disilicate does not lie on the straight line under consideration, the liquid cannot crystallize completely to a mixture of these two phases and it will follow the disilicate boundary to the ternary eutectic, at which quartz should appear, and the last trace of liquid disappear. Because of the reluctance of these mixtures to crystallize, however, equilibrium practically cannot be reached, and the above crystallization course is not experimentally realizable, at least in its lower temperatures. Under ordinary conditions, it is not even possible to reach the disilicate boundary, and the final result will be a devitrified glass containing $Na_2O \cdot 3CaO \cdot 6SiO_2$ and probably also $CaO \cdot SiO_2$.

Because of the difficulty of obtaining equilibrium, it is not worth while to outline all the various possible crystallization courses of the various initial mixtures, but it is interesting to point out the variation from the above sequence of mixtures lying in the $CaO \cdot SiO_2$ field, but not on the straight line already discussed, and also to trace the crystallization path of a glass lying in the tridymite field. If $CaO \cdot SiO_2$ crystallizes from any glass, the composition of the mother liquor will follow the straight line passing through $CaO \cdot SiO_2$ and the original glass composition. If this line cuts the $CaO \cdot SiO_2$-tridymite boundary, the two phases should crystallize together, and the liquid follow the boundary curve. This, however, will rarely happen. It is an observed fact that the secondary crystallization in mixtures such as the soda-lime glasses is harder to obtain than is the primary, no matter which is primary and which the secondary phase; and it is rarely possible to trace a boundary curve for any considerable distance. If the line through $CaO \cdot SiO_2$ and the original glass cuts the boundary curve $Na_2O \cdot 3CaO \cdot 6SiO_2$, this phase should appear, the $CaO \cdot SiO_2$ should react with liquid to form the 1:3:6 compound, and the residual liquid will follow the boundary curve. If the intersection with the boundary curve is at a lower SiO_2 content than the join $CaO \cdot SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$, the liquid will follow the short path to the invariant point $Na_2O \cdot 2CaO \cdot 3SiO_2$–$CaO \cdot SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$, then, after all the $CaO \cdot SiO_2$ has disappeared by reacting to form the 1:3:6 compound, trace the boundary curve $Na_2O \cdot 2CaO \cdot 3SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$ to the invariant point $Na_2O \cdot 2SiO_2$–$Na_2O \cdot 2CaO \cdot 3SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$. At this point reaction should take

place until $Na_2O{\cdot}2CaO{\cdot}3SiO_2$ has disappeared, after which the liquid should follow the $Na_2O{\cdot}2SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$ boundary to the ternary eutectic. If the intersection of the line joining the composition of the original glass with $CaO{\cdot}SiO_2$ cuts the $CaO{\cdot}SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$ boundary on the opposite, and more siliceous side of the join $CaO{\cdot}SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$, the liquid should follow the boundary to the invariant point $Na_2O{\cdot}3CaO{\cdot}6SiO_2$–$CaO{\cdot}SiO_2$–tridymite, then follow the tridymite–1:3:6 boundary until 870°, when the tridymite should invert to quartz, and the liquid should then follow the quartz–1:3:6 boundary to the eutectic. These reactions are very slow, and it is hardly possible, even experimentally, to follow them to completion. It is not to be expected that they will be met with in glass works practice.

A glass originally in the tridymite field will deposit tridymite as primary phase, and the liquid will follow the straight line passing through the original glass composition and the SiO_2 apex, until it meets either the $CaO{\cdot}SiO_2$ or the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ boundary. After that it will proceed to the same ternary eutectic, as previously described. It will be observed that every glass in the region under consideration has as its final crystallization product the same three phases, quartz, $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and $Na_2O{\cdot}2SiO_2$. the ternary eutectic at 725° dominates the glass field. It has repeatedly been emphasized that to follow the equilibrium crystallization to completion is not possible; but it does not follow that this diagram does not give information as to the crystallization which will take place. It will rarely be found that the first phase to appear is other than that corresponding to the field within which its composition lies. The only case in which there is a probability of this is in the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ field near the $CaO{\cdot}SiO_2$–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$ boundary, especially near the tridymite invariant point. Here there is a possibility of either $CaO{\cdot}SiO_2$ or tridymite coming out as metastable phases when glass is cooling down; but such appearance of metastable phases is not to be expected on heating. The failure of the secondary crystallization to appear at a boundary within a given time has often been observed, but it will appear if time be given. The failure of a given phase to react to form another and stable phase, for example, of $CaO{\cdot}SiO_2$, to react to form $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, or of tridymite to form quartz, has often been observed; but $CaO{\cdot}SiO_2$ has not been observed on heating a glass within the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ field, nor has the latter compound appeared in the quartz or tridymite field. Metastable crystallization is rarely observed in the $Na_2O{\cdot}2CaO{\cdot}3SiO_2$ or the $Na_2O{\cdot}2SiO_2$ field.

At an earlier point in the discussion the importance of starting with a homogeneous glass was emphasized, and it was also pointed out that the way in which the crystals were distributed in the glass grains when heated just below the liquidus is a sensitive test of homogeneity. In this connec-

tion it is of interest to examine the temperature-composition curves of Figs. 4, 5, and 6. Figure 4 has already been discussed. The average slope along this curve is about 35° for 1%, *i.e.*, an increase in CaO content of 1% raises the liquidus 35°. Figure 3 shows the temperature variation along the boundary between the forms of SiO_2, and the phases $Na_2O \cdot 2SiO_2$, $Na_2O \cdot 3CaO \cdot 6SiO_2$, and $CaO \cdot SiO_2$, successively. Here also the average slope is about 35° per 1% CaO. Figure 5 shows the variation in temperature with SiO_2 content along two sections, one with 8% CaO, the other with 12% CaO. In both, the temperature falls rapidly to the $Na_2O \cdot 2CaO \cdot 3SiO_2$–$Na_2O \cdot 3CaO \cdot 6SiO_2$ boundary, increases slightly over the 1:3:6 field to the tridymite boundary, and increases rapidly in the tridymite field. The average slope of each curve in the tridymite field is 75° per 1% SiO_2, or 7.5° for a composition difference of only 0.1%. From this it is evident that the greatest care must be taken to insure uniformity in studies of the devitrification of glass. The composition differences which manifest themselves as cords or ream in ordinary glassware may cause a difference in freezing point of over 100°, and to secure homogeneity sufficient to meet the requirements of equilibrium studies demands a uniformity of composition rarely met with in commercial glasses.

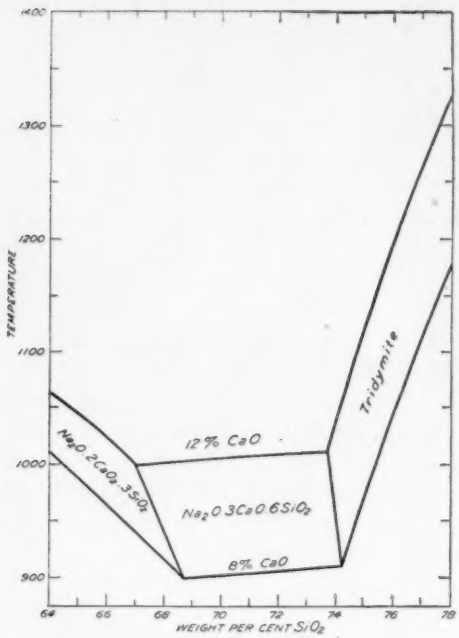

FIG. 5.—The variation of temperature with weight % SiO_2 along two straight lines of constant CaO content.

Discussion of the Literature Relative to Devitrification

The literature relative to the devitrification of glass has largely appeared since the publication of the fundamental study of Morey and Bowen, as will be seen from the references given below. Schaller[15] gives no details of procedure but presents two graphs giving "upper devitrification temperature" as a function of composition. One of these refers to Na_2O-

[15] R. Schaller, *Z. angew. Chem.*, **49**, 2369 (1909). It should be mentioned that this reference was not known to the writer at the time of previous discussions of this system.

SiO_2–SiO_2 mixtures, and roughly agrees in shape with the liquidus curves of that system,[16] but the temperatures are from 50 to 100° too low. A curve is given showing the "temperatures of devitrification" (presumably also meaning the upper limit, which should be identical with the liquidus temperature) in the ternary system, and here the agreement is not so good Schaller, however, clearly recognized the nature of the problem and the

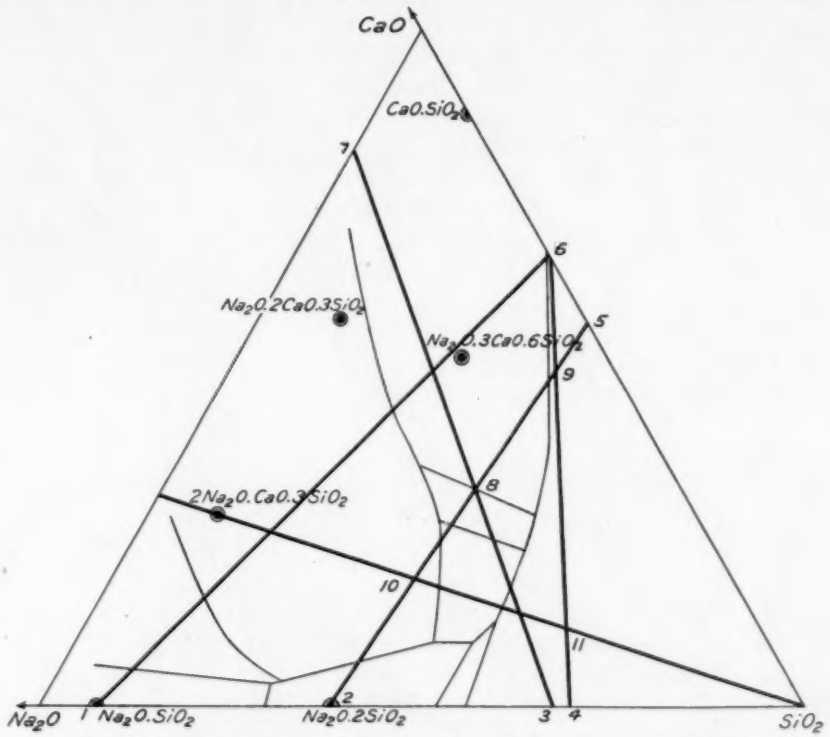

FIG. 6.—The partition of the system Na_2O–CaO–SiO_2 into fields according to Gelstharp and Parkinson.

importance of the liquidus temperature. For example (p. 2370) he says: "Wird ein Glas im Hüttenbetrieb verarbeitet, so muss es längere Zeit auf einer Temperatur gehalten werden, bei der die Zähigkeit der Masse für die Verarbeitung eine günstige ist. Würde bei dieser Temperatur leicht Krystallisation eintreten, so wäre die Schmeltze nicht brauchbar. Ein Glas wird sich also um so günstiger verhalten, je zähflüssiger es bei der oberen Entglasungstemperatur ist."

[16] G. W. Morey and N. L. Bowen, *Jour. Phys. Chem.*, **28**, 1167 (1924). F. C. Kracek, *ibid.*, **34**, 1583 (1930).

The work of Gelstharp and Parkinson[17] divided the ternary system Na_2O–CaO–SiO_2 into several fields, which are shown in Fig. 6, superimposed on the diagram of Morey and Bowen. They state that mixtures less siliceous than those on the orthosilicate join, from $2Na_2O{\cdot}SiO_2$ to $2CaO{\cdot}SiO_2$ (not shown in Fig. 6) only yield basic slags and infusible mixtures of silicates. From this line to that joining sodium metasilicate with the calcium metasilicate-cristobalite eutectic (line 1–6) transparent glasses are obtained only on rapid cooling, otherwise the melt devitrifies. This is certainly true of the melts between orthosilicate and metasilicate, but where this line cuts the $Na_2O{\cdot}2CaO{\cdot}3SiO_2$ boundary the glasses are much easier to obtain. Since, however, there has been as yet no rational method of comparing or even defining that quantity which may loosely be called the relative crystallizability of two glasses; and, moreover, since it is evident that the transition from one type to another is not sharp but continuous, it is evident that these boundaries are arbitrary and devoid of precise meaning. Between 1–6 and 4–6, the line joining the composition (not compound) $Na_2O{\cdot}5SiO_2$ with the above eutectic, is the field of transparent glasses proper, including technical glass. Mixtures more siliceous than the line 4–6 yield opalescent or opaque glasses on cooling. These fields are roughly in accord with the fields of the equilibrium diagram. The line 4–6 cuts off the field of tridymite not far from the 1250° isotherm, in the region of not too high CaO content, and the triangle 1–4–6 certainly includes all glass compositions which could be made on a technical scale. But this field is further cut off by the line 2–5, joining the composition of the compound $Na_2O{\cdot}2SiO_2$ with the composition (not compound) $CaO{\cdot}2SiO_2$, on the basis that glasses between 1–6 and 2–5 so excluded are mechanically weak, do not readily resist dilute acids, carbon dioxide, water, etc., and tend to devitrify readily. This leaves only the triangle 2–4–9 as taking in the domain of glasses, and this domain is further restricted by the line 3–7 which represents the locus of compositions having an Na_2O content 22% of the SiO_2 content. Glasses containing a larger proportion of Na_2O are too readily attacked by water. "For some purposes this limiting line may be set to a lower standard, but for plate glass 22% is even much too low." This leaves as the technical glass field the triangle 8–9–10, including the major portion of the tridymite boundary, of the field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and a small part of the $CaO{\cdot}SiO_2$ field. The upper portion of the field is out of the question for practical purposes, as its liquidus is above 1350° and crystals are freely formed in five minutes. Nevertheless, the field so defined while containing portions unsuitable for technical glass, does include all compositions which are suitable, except for special cases in which a greater alkali content than 22% of the SiO_2, or in which for special reasons the greater tendency toward

[17] F. Gelstharp and J. C. Parkinson, *Trans. Amer. Ceram. Soc.*, **16**, 109 (1914).

crystallization is not objectionable. A further subdivision was made by Gelstharp and Parkinson, namely that glasses containing more lime than the ratio $2Na_2O$:CaO, *i.e.*, than the line from the SiO_2 apex through the compound $2Na_2O \cdot CaO \cdot 3SiO_2$, could not be made with soda ash (Na_2CO_3) alone, but salt cake (Na_2SO_4) must be added. This may be true under certain technical conditions, but is not true in general.

Peddle[18] studied the devitrification of soda-lime glasses as part of his valuable contribution to the science of glass, but his method makes direct comparison with the present work difficult. He heated small pieces in a muffle for 6 hours at 900°, then cooled in 12 hours. There is, of course, no way to distinguish the effects produced at 900° from those taking place during the cooling. The following table gives the liquidus temperature and primary phase of his glasses, as well as his observations. Two series of glasses were used, of the general formula $100SiO_2 \cdot 40Na_2O \cdot xCaO$ and $100SiO_2 \cdot 20Na_2O \cdot xCaO$. The first of these represents glasses on the straight line in the ternary diagram from 29.2 Na_2O, 70.8 SiO_2, the other, from 17.1 Na_2O, 82.9 SiO_2, to the CaO corner.

TABLE IV

DEVITRIFICATION RESULTS OF PEDDLE

	Liquidus Data (Morey)		
CaO (%)	Temp. (°C)	Phase	Peddle's remarks
		Series $100SiO_2 \cdot 40Na_2O \cdot xCaO$	
3.22	840	$Na_2O \cdot 2SiO_2$	No devitrification; melted
6.23	910	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Melted; no devitrification
9.07	1020	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Melted; no devitrification
11.73	1075	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Melted; semiporcelain mass; devitrification
16.62	1190	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Not melted; semiporcelain mass; devitrification
21.00	1240	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Not melted; semiporcelain mass; devitrification
		Series $100SiO_2 \cdot 20Na_2O \cdot xCaO$	
3.73	1170	Tridymite	Not melted; heavy white layer of devitrified silica
7.19	1100	Tridymite	Not melted; heavy white layer of devitrified silica
10.41	1030	Tridymite	Melted; slight white layer initial devitrification
13.42	1050	$CaO \cdot SiO_2$	Melted; no devitrification
18.86	1180	$CaO \cdot SiO_2$	Just melted; white porcelain mass; crystalline devitrification
23.65	1250	$CaO \cdot SiO_2$	Not melted; white porcelain mass; crystalline devitrification

It will be observed that only the first glass is above its liquidus temperature at 900°, although the second glass is so close that it also may well have been above the liquidus. This first series of glasses crosses the $Na_2O \cdot 2SiO_2$

[18] C. J. Peddle, *Jour. Soc. Glass Tech.*, **4**, 35 (1920).

field and passes into the $Na_2O \cdot 2CaO \cdot 3SiO_2$ field. This latter compound crystallizes easily. It is strange that the glass with 9.07% CaO did not crystallize, because two glasses not very different in composition and lying near this same line, namely, those with a liquidus temperature of 907° and 1014°, crystallized freely in one hour. In the other series all the glasses are well below the liquidus at 900°. This series starts in the tridymite field; the temperature falls to the glass with 10.41% CaO, which is practically on the $Na_2O \cdot 3CaO \cdot 6SiO_2$-tridymite boundary, then rises across the fields of $Na_2O \cdot 3CaO \cdot 6SiO_2$, and $CaO \cdot SiO_2$, the latter in the two forms wollastonite and pseudo-wollastonite. All of the glasses in this series had devitrified; the term "melted" used in Peddle's description referred to the flowing of the glass, and it is to be inferred that in those that had not "melted" devitrification took place too rapidly for the glass to change its shape markedly.

Peddle also found that in cooling either from 1350° or from 1100° to room temperature in 12 hours there was no sign of devitrification in the series with $40Na_2O$, while in the second series the first and last glasses showed separation of silica or of calcium silicate, respectively.

Arthur[19] discussed the chemical composition of window glass, on the basis of the equilibrium diagram of Morey and Bowen. He also constructed from their work sections through the solid model showing the variation of temperature with composition of mixtures containing 11% CaO, and for mixtures containing 72% SiO_2.

Zschimmer and Dietzel[20] made a detailed study of the devitrification of a technical soda-lime glass, of the composition: SiO_2, 70.15; Al_2O_3, 1.09; Fe_2O_3 0.21; CaO, 15.62; Na_2O, 11.79; K_2O, 0.16; As_2O_5, 0.14; SO_3, 0.84, and found the upper limit of devitrification to be 1140°. The nearest glass in composition studied by Morey and Bowen (2811C, No. 36 of this paper) had a liquidus temperature of 1106°, and they suggest that the difference is caused either by the slight composition difference, especially by the presence of some of the additional components in their glass, or that Morey and Bowen did not leave their glass long enough for equilibrium to be attained, suggesting that if the glass had been left longer at the highest temperature given in Table II of Morey and Bowen's paper, crystals would have formed. Unfortunately, it was not made clear in that paper that the initial charge was already crystalline, in that case being the one mentioned as being treated for 2 hours at 1075°; and the temperature given is that at which the crystals disappear in the given time. In the study of Morey and Bowen, as in the present study, in cases in which there was question of

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[19] Edwin P. Arthur, *Jour. Amer. Ceram. Soc.*, **9**, 203 (1926).

[20] E. Zschimmer and A. Dietzel, *Sprechsaal*, **60**, 110, 129, 165, 186, 204 (1927). See also Zschimmer, *Jour. Soc. Glass Tech.*, **12**, 92 (1928).

difficulty in making sure of equilibrium, two quenches, one glass and one containing crystal, were hung side by side in the furnace. Unfortunately, none of that glass is available, but the newer results given in this paper agreed with the temperature of 1106° given for it. It therefore became of interest to ascertain the cause of the difference between the two sets of results, especially since previous results, reported in a paper to be published at the same time as this one, on the effect of alumina on a glass lying in the tridymite field, showed a sharp lowering of melting point for 1% of alumina. It will be observed that in Zschimmer and Dietzel's glass the sum of SiO_2, CaO and (Na_2O+K_2O) is 97.72%, and on recalculation to 100% this is not far from the glass No. 37 of the present paper, containing 72.15SiO_2, 16.03CaO, 11.82Na_2O, and having a liquidus temperature of 1139.° Accordingly, 0.5 g. of this glass was intimately mixed with 6.5 mg. Al_2O_3, and the resulting glass twice fined with intermediate pulverization to pass 120-mesh bolting cloth. The loss in weight in the two meltings was only 0.3 mg. The composition of the resulting glass was therefore SiO_2, 71.22; CaO, 15.82; Al_2O_3, 1.29; Na_2O, 11.67, and it was found to have a liquidus temperature of 1161°, showing that the addition of 1.3% of alumina in this case had raised the liquidus temperature 22°. In view of this fact, the difference between the results of Zschimmer and Dietzel and of Morey and Bowen is rendered less surprising, and it is not improbable

TABLE V

RESULTS OF DIETZEL ON UPPER LIMIT OF DEVITRIFICATION OF SODA-LIME GLASSES

	Composition				Devitrification temperatures of Dietzel			Liquidus data (Morey)	
No.	Na_2O	CaO	SiO_2	Al_2O_3 +Fe_2O_3	Most rapid growth (°C)	Upper limit (°C)	Phase	Liquidus (°C)	Primary phase
3	11.93	10.01	77.92	0.13	1130	1252	Cristobalite	1268	Tridymite
4	11.99	12.05	75.72	.24	1085	(1225)	Cristobalite	1170	Tridymite
5	11.96	14.00	73.90	.14	975	1142	Cristobalite	1110	Tridymite
6	12.05	16.07	71.67	.21	990	(1105)	$CaO{\cdot}SiO_2$	1138	$CaO{\cdot}SiO_2$
8	14.05	8.63	77.68	.24	1100	(1200)	Cristobalite	1170	Tridymite
9	13.95	10.02	75.82	.21	1055	(1150)	Cristobalite	1125	Tridymite
10	13.93	12.01	73.94	.12	945	(1055)	Cristobalite	1050	Tridymite
11	14.03	14.06	71.65	.26	980	(1055)	Wollastonite	1060	$CaO{\cdot}SiO_2$
12	13.97	15.98	69.92	.13	980	(1100)	Wollastonite	1110	$CaO{\cdot}SiO_2$
13	15.92	5.98	78.95	.15	1080	(1160)	Cristobalite	1180	Tridymite
14	15.95	8.10	75.85	.10	1050	(1100)	Cristobalite	1090	Tridymite
15	15.97	10.08	73.76	.19	920	(980)	Cristobalite	970	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
16	15.92	12.02	71.84	.21	925	(995)	Wollastonite	1010	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
17	15.96	13.97	69.93	.14	980	1040	Wollastonite	1050	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
18	16.00	16.02	67.71	.27	1005	(1080)	P. Wollastonite	1090	$CaO{\cdot}SiO_2$
19	17.94	6.01	75.89	.16	910	1005	Cristobalite	1010	Tridymite
20	18.05	8.05	73.79	.11	875	(925)	Cristobalite	910	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
21	17.91	10.67	71.73	.29	900	(960)	Wollastonite	980	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
22	18.00	12.03	69.73	.24	950	(990)	Wollastonite	1005	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
23	17.97	14.06	67.78	.19	975	(1030)	Wollastonite	1044	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
24	17.95	15.97	65.83	.25	1000	(1055)	Wollastonite	1075	$CaO{\cdot}SiO_2$

that both the As_2O_5 and SO_3 present in the former's glass may have raised the freezing point.

In a later paper, Dietzel[21] studied the rate of devitrification of a number of glasses included within the limits of this paper, and presents his results chiefly in the form of curves giving the "velocity of crystallization" as a function of temperature, which, when extrapolated to their upper intersection, presumably give the upper limiting devitrification temperature, which should coincide with the liquidus temperature. Dietzel does not give this temperature for all his glasses, but the extrapolation of the curves is given in his figures, making it easy to read off the upper devitrification temperature from the temperature scale given. The list of glasses lying within the limits of this paper is given in Table V. Column 1 gives Dietzel's numbers: 2, 3, 4, and 5, the compositions, as determined by analysis; 6, the temperature of most rapid growth of crystals; 7, the upper devitrification limit, the values in parenthesis being read off from the curves; 8, the nature of the crystalline phase; 9, the liquidus temperature of the glass having the same CaO and SiO_2 content, as interpolated in Fig. 2; 10. the nature of the primary phase. The agreement between Dietzel's upper devitrification temperature and the liquidus temperature is, on the whole, excellent, especially when it is remembered that frequently the extrapolation of the curve of crystallization velocity was 50° and sometimes 100°. The best agreement is usually found where the extrapolation was the shortest. There is not a good agreement between the identification of the primary phase in the two sets of results. For the identification of $Na_2O \cdot 3CaO \cdot 6SiO_2$ Dietzel evidently relied on X-ray photographs, but the discrimination between it and wollastonite is easy with the petrographic microscope. In the experiments described in this paper wollastonite was never observed to form in the $Na_2O \cdot 3CaO \cdot 6SiO_2$ field, and it is probable that the discrepancy is caused by a failure to differentiate between the two compounds. Both tend to form long needles, often grouped together in bundles, and only by careful measurement of refractive index can they be distinguished, but this means of identification is positive. The frequent occurrence of cristobalite instead of tridymite is less difficult to explain, because cristobalite frequently appears in the tridymite field. Nevertheless, the primary phase was positively identified as tridymite in most of the experiments of this paper, and in the few cases in which cristobalite appeared there was always tridymite with it. Here again there is reason to doubt the effectiveness of his method of differentiation between these two phases.

One of the most recent studies of the devitrification of glass is that of

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[21] Adolph Dietzel, *Sprechsaal*, **60**, Nos. 7–12 (1929); reprinted in *Glass Ind.*, **11** (1930).

Parmelee and Monack,[22] who studied the relative stabilities of various commercial glasses, and determined some time-temperature curves of visible devitrification. The relative stabilities of the glasses were determined by a "thermal treatment" which consisted in "heating them in small crucibles until they were fluid, and then slowly cooling them so that a period of 12 to 15 hours was required to reach room temperature...". This description is too vague to enable any check to be made, since even in the discussion no mention is made of the temperature at which they were held for 12 to 15 hours; and in addition the phrase "slow cooling" does not convey definite information, even though 12 to 15 hours were required to reach room temperature. If heat is cut off from a furnace at 1000°, it may require a certain length of time to cool to room temperature, but only a small part of that time is passed in cooling through the first 100 to 200°. But that portion of the cooling is all that is important in such a case; because, as is evident from all the work done on the rate of devitrification of glass, including that of Parmelee and Monack, the rate of devitrification falls off rapidly with decreasing temperature after the "temperature of maximum rate of crystallization" is passed. Such a test is apt to give most misleading results if not carried out with some knowledge of the fundamental phase equilibrium diagram. For example, if the glass is held for 12 to 15 hours at a temperature above its liquidus, then allowed to cool slowly, unless it is a very inferior glass it will not devitrify; while, on the other hand, if this period of long heating is not too far below the liquidus, it will devitrify. It is unfortunate that the essential data are not given, but it is probable that the Pyrex glass was so treated. Just below its liquidus Pyrex will devitrify in 12 hours, but from the practical point of view it is a glass which gives no trouble from devitrification.

Parmelee and Monack give on page 336 the data for the construction of a time-temperature curve of devitrification of three glasses whose composition is given in their Table I. Unfortunately, alkalis were determined by difference, so not only does the alkali value carry all the analytical errors of the entire analysis, but also there is no separation of Na_2O and K_2O, hence it is not possible to tell whether they are soda-lime, or mixed soda-potash-lime, glasses. Numbers 4 and 13 are described as a wire glass and a plate glass, respectively, and it is probable that the alkali in them was essentially soda, and hence they are comparable with the glasses discussed in this paper. Number 4 has the composition SiO_2, 73.2; CaO, 9.5; MgO, 0.5; Al_2O_3 + Fe_2O_3, 0.8. Considering only the SiO_2 and (CaO + MgO), this is not far from glass No. 22 of this paper, which contains SiO_2, 73.85; CaO, 9.98; and has a liquidus temperature of 974°. A glass of this composition should have as its upper limit of crystallization 974°, yet Parmelee and

[22] C. W. Parmelee and A. J. Monack, *Jour. Soc. Glass Tech.*, **13**, 322 (1929).

Monack give the following time-temperature relations: 951°, 5 min.; 1000°, 8 min.; 1046°, 30 min.; 1076°, 55 min.; 1105°, 87 min. Such a discrepancy is inexplicable. To eliminate definitely the effect of the Al_2O_3 and MgO, enough of these latter components were added to glass No. 21 (SiO_2, 73.93; CaO, 11.03; Na_2O, 15.04, liquidus 994°, phase tridymite) to give a glass near to Parmelee and Monack's No. 4. The additional components were well mixed with the powdered glass, the mixture melted, fined, powdered to pass 120-mesh bolting cloth, and again fined, the last heating at 1350° over night. The resulting glass had the composition, after allowing for the loss of 0.4% Na_2O, of SiO_2, 73.75; CaO, 9.58; MgO, 0.50; Al_2O_3, 0.79. It had a liquidus temperature of 979°, with primary phase $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and 2° below the liquidus the glass crystallized in two hours, while crystals dissolved 2° above the liquidus when left over night (18 hr.). Hence addition of the Al_2O_3 and MgO lowered the liquidus 14° and shifted the glass from the tridymite to the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ field and the above discrepancy became irreconcilable. Similarly, Parmelee and Monack's Table II refers to their glass No. 13 (SiO_2, 71.8; CaO, 12.8; MgO, 0.7; $Al_2O_3 + Fe_2O_3$, 0.6) which is to be compared with a glass approximately 72% SiO_2, 13.5 CaO, which would lie just inside the field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and would have a liquidus temperature of not over 1050°. The time-temperature data of Table II give for it: 900°, 2 min.; 1000°, 2 min.; 1015°, 3 min.; 1039°, 10 min.; 1085°, 60 min.; 1108°, more than 130 min; again an irreconcilable discrepancy. It is probable that the glass No. 9, a crown optical glass, contains K_2O and hence is not directly comparable with the glass having the same SiO_2 and CaO content in either the Na_2O–CaO–SiO_2 or the K_2O–CaO–SiO_2 systems, which glasses would have liquidus temperatures of approximately 1070° and 1150°; but in any case the statement: "Apparently the composition is so well balanced that the glass is not saturated with respect to any silicates of calcium or of sodium and calcium" is meaningless. Above the liquidus, it is unsaturated by definition; at the liquidus it becomes saturated with the primary phase; and at lower temperatures with additional phases, and this glass would crystallize without difficulty at the proper temperature.

Kitaigorodsky[23] has studied glass devitrification by first heating the samples in small crucibles containing 5 to 6 grams, to a temperature sufficient to dissolve all crystals already formed, then quickly cooling to the temperature desired, and holding at constant temperature for 3, 6, 9, or 12 hours. Most of his glasses were more complex than those of this system, but his group III, glasses 300, 370, 371, and 372 had the composition ($6SiO_2{\cdot}CaO$) plus 1.0, 1.1, 1.2, and 1.3 Na_2O, respectively. The first of these is in the tridymite field, with liquidus about 1100°; the last in the

[23] J. J. Kitaigorodsky, *Jour. Soc. Glass Tech.*, **13**, 219 (1929)

$Na_2O \cdot 3CaO \cdot 6SiO_2$ field, with liquidus about 990°; and all lie on the straight line joining the composition $Na_2O \cdot CaO \cdot 6SiO_2$ with the Na_2O apex. Glass 370 devitrified at all temperatures employed from 700 to 1100°; 371 at 1000°; while 371 and 372 did not crystallize at 1100°, 371 and 372 both crystallized at 900°, and 300 was included among the glasses having the greatest tendency to crystallize. These observations are in harmony with the liquidus diagram, which, however, yields much more information.

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THE EFFECT OF MAGNESIA ON THE DEVITRIFICATION OF A SODA-LIME-SILICA GLASS[1]

By George W. Morey

ABSTRACT

The effect of magnesia on the devitrification of a certain soda-lime-silica glass has been ascertained. The initial glass had a composition $1.15Na_2O{\cdot}0.84CaO{\cdot}6SiO_2$, and tridymite separated as primary phase. On substitution of MgO for CaO, tridymite remained primary phase, and the melting point was lowered, but the curve shows a double inflection. Addition of 2% of MgO lowered the melting point almost 200°, with the glass passing from the field of tridymite to that of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, but with more than 3%, MgO diopside became the primary phase, and the melting point rapidly increased.

Introduction

Because of the frequent occurrence of small amounts of magnesia in commercial soda-lime-silica glasses, it becomes of interest to ascertain its effect on the liquidus temperature, and on the nature of the crystalline phase appearing as primary phase. The complete solution of this problem would require a knowledge of the liquidus relations of the quaternary system, Na_2O–CaO–MgO–SiO_2, and the experimental results presented in this paper comprise only two limited excursions into the tetrahedron representing the quaternary system, both starting from the same point on the Na_2O–CaO–SiO_2 side, and proceeding in arbitrary directions. In the first series, CaO is replaced by MgO in a parent glass near the empirical composition $Na_2O{\cdot}CaO{\cdot}6SiO_2$, with the final glass having a composition near $Na_2O{\cdot}MgO{\cdot}6SiO_2$. In the second series, MgO is added to the same glass, tracing a straight line through the solid model from the given point on the Na_2O–CaO–SiO_2 side toward the MgO apex. The first series corresponds with the glasses whose viscosity-temperature curves were determined by English[2] and discussed by Fulcher,[3] and, indeed, it was as a result of a discussion with Dr. Fulcher that the study was started.

Experimental

The methods used in the preparation of the glasses and the study of their melting relations were those commonly used in this work, which have been described several times, and need not be further discussed.[4]

The results are assembled in Tables I and II, and shown graphically in Fig. 1. Table I gives the composition of the glasses, their liquidus temperatures, and the primary phase; and Table II gives enough of the experimental results to substantiate Table I.

[1] Received July 16, 1930.

[2] S. English, *Jour. Soc. Glass Tech.*, **9**, 83 (1925).

[3] G. S. Fulcher, *Jour. Amer. Ceram. Soc.*, **8** [12], 789 (1925).

[4] See the preceding paper by the present author, p. 683, this issue.

TABLE I

LIQUIDUS TEMPERATURES OF SOME Na_2O–CaO–MgO–SiO_2 GLASSES

No.	Na_2O	CaO	MgO	SiO_2	Temp. °C	Phase
			(Initial glass $1.15Na_2O{\cdot}0.84CaO{\cdot}6SiO_2$)			
1	14.86	9.83		75.25	1085	Tridymite
			Series I			
2	15.0	6.4	2.5	76.1	1060	"
3	15.1	4.6	3.8	76.5	1033	"
4	15.2	2.8	5.2	76.8	1025	"
5	16.1		7.1	76.8	1013	"
			(Final glass $1.15Na_2O{\cdot}0.84MgO{\cdot}6SiO_2$)			
			Series II			
6	14.5	9.6	2.4	73.5	895	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$
7	14.2	9.3	4.8	71.7	1010	$CaO{\cdot}MgO{\cdot}2SiO_2$
8	13.5	8.9	9.1	68.5	1144	$CaO{\cdot}MgO{\cdot}2SiO_2$
9	12.4	8.2	16.7	62.7	1218	$CaO{\cdot}MgO{\cdot}2SiO_2$

TABLE II

QUENCHING DATA FOR THE GLASSES OF TABLE I

No.	Initial condition	Temp. °C	Time	Final condition
1			(Interpolated from ternary system $Na_2O{\cdot}SiO_2$–$CaO{\cdot}SiO_2$–SiO_2)	
2	G	907	24 h	Glass; beautiful cristobalite
	G	1030	3 h	Glass; tridymite
	G	1055	17 h	Glass; trace tridymite
	X	1062	5 h	Glass
3	G	1012	4 h	Glass; tridymite
	G	1030	4 h	Glass; rare tridymite
	X	1035	1 h	Glass
4	G	1020	17 h	Glass; tridymite
	X	1030	4 h	Glass
5	G	980	17 h	Glass; tridymite
	G	1010	2 h	Glass; rare tridymite
	X	1017	4 h	Glass
			Series II	
6	G	800	16 h	Glass; many fine needles $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	891	14 h	Glass; rare $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	897	2 h	Glass
7	G	870	4 d	Glass; much $Na_2O{\cdot}3CaO{\cdot}6SiO_2$; rare $CaO{\cdot}MgO{\cdot}2SiO_2$
	G	1005	14 h	Glass; few needles $CaO{\cdot}MgO{\cdot}2SiO_2$
	X	1015	4 h	Glass
8	G	1000	14 h	Glass; numerous $CaO{\cdot}MgO{\cdot}2SiO_2$
	G	1142	2 h	Glass; $CaO{\cdot}MgO{\cdot}2SiO_2$
9	G	1170	14 h	Glass; $CaO{\cdot}MgO{\cdot}2SiO_2$, of normal properties, hence there is no solid solution formed
	G	1217	30 m	Glass; rare well-formed $CaO{\cdot}MgO{\cdot}2SiO_2$
	X	1220	30 m	Glass

Curve I of Fig. 1 refers to the glasses obtained by replacing CaO by MgO, and it is evident that the melting point is lowered and that the glass remains in the tridymite field. The curve, however, shows an in-

flection which is almost a minimum, which would indicate that the isothermal surfaces in the tridymite have a marked convexity toward the SiO_2 apex in the solid model.

Curve II shows the effect of addition of MgO, and the contrast between the two curves is striking. While the glass is initially in the tridymite field, on addition of 2.4% MgO it has passed into the field of the compound $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and the melting point has been lowered almost 200°. On this line through the tetrahedron, the compound $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ has a very narrow field, but it is probable that by further experimentation, mixtures could be found in which its field would extend further into the quaternary system, with benefit both to the ease of melting and to thermal stability. On continued addition of MgO, the mineral diopside, $CaO{\cdot}MgO{\cdot}2SiO_2$, a double metasilicate of CaO and MgO is formed, and remains the stable phase far into the quaternary system. Diopside crystallizes readily from these melts, and glasses corresponding to those from which it has been found to separate would not prove suitable for manufacture on a large scale.

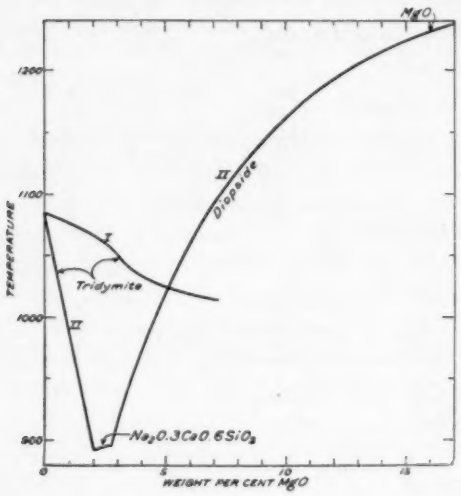

FIG. 1.—Liquidus temperatures of some Na_2O–CaO–MgO–SiO_2 glasses. Curve I shows the effect of replacing CaO by MgO in a glass of the composition $1.15Na_2O{\cdot}0.84CaO{\cdot}6SiO_2$; curve II shows the effect of adding MgO to the same glass.

A further experiment was made to see if a quaternary compound of the nature of a triple metasilicate of Na_2O, CaO, and MgO is formed in this system. On crystallizing a glass of this composition at 750°, it gave a mixture of about 50% diopside, the remainder being chiefly an unknown compound with weak birefringence, marked polysynthetic twinning, refractive index 1.585. In addition, there was present a small amount of another phase which might have been forsterite, $2MgO{\cdot}SiO_2$, and a negligible quantity of glass. There is evidently an unknown compound formed in the system, but it cannot have the composition of a triple metasilicate. On heating these crystals to 875°, it was found that melting had begun at the expense of the new crystalline phase. The primary phase at the liquidus is diopside.

It is evident that the melting relations in the quaternary system will

be exceedingly complicated in the region of the metasilicates and less siliceous compounds, but no more experiments have been made in this interesting system. Some observations on glasses containing both MgO and Al_2O_3 will be found in a paper on the effect of alumina on the devitrification of soda-lime glasses[5] appearing simultaneously with the present paper, but the problem is one which deserves more intensive study.

Acknowledgment It is a pleasure to acknowledge my indebtedness to my colleagues Dr. N. L. Bowen and Dr. H. E. Merwin for their aid in the petrographic examination.

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[5] G. W. Morey, see p. 723, this issue.

THE EFFECT OF ALUMINA ON THE DEVITRIFICATION OF A SODA-LIME-SILICA GLASS[1]

By George W. Morey

ABSTRACT

The effect of Al_2O_3 on the devitrification temperature of a soda-lime-silica glass approximately of the composition $Na_2O{\cdot}CaO{\cdot}6SiO_2$ has been studied in two series of experiments. In one of these CaO was partially replaced by Al_2O_3 until the final glass had the composition of the mineral albite, $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$; and in this series of experiments the melting point of the glass was first lowered, until the glass passed from the tridymite into the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ field; then rose slightly to a maximum, fell until the glass entered the field of $CaO{\cdot}SiO_2$, and then rose rapidly until the field of albite was reached. Glasses near albite in composition are practically impossible to crystallize in the dry way. In the second series of experiments, Al_2O_3 was added to the same glass, and it was found that the fields of tridymite and $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ were quickly passed through, with a smaller lowering of melting point than in the preceding series, after which the melting point rapidly increased, with $CaO{\cdot}SiO_2$ as primary phase. It is shown that no generalizations can be made as to the effect of alumina on the devitrification of soda-lime glass. The problem is one of the freezing-point relations in a four-component system, and in the absence of definite knowledge of the liquidus temperatures and corresponding stability regions in that four-component system general statements would probably be misleading. In addition, the devitrification of some five-component soda-lime glasses containing both Al_2O_3 and MgO is discussed.

That the presence of alumina greatly diminishes the tendency of a soda-lime-silica glass to devitrify has been known since Schott[2] showed that the superiority for table and blow-pipe working of certain glasses made in the Thuringian Forest was caused by the presence of almost 4% of alumina in the sand used, and that addition of alumina to the usual glass batches greatly improved the tendency toward devitrification of the resulting product. The observations of Schott, confirmed as a matter of common experience by many workers with glass, have to do with the velocity of the devitrification under conditions which are not only variable but also practically undefined, and to correlate these observations with the effect of alumina on the temperature of initial devitrification of glass seemed desirable, inasmuch as this temperature is the only one having to do with the devitrification process which represents a definitely reproducible and fixed point.

To study adequately the effect of alumina on the devitrification of soda-lime glasses would necessitate the working out of a large part of the quaternary system Na_2O–CaO–Al_2O_3–SiO_2, a major research of great magnitude. The present study comprises only restricted excursions into the quaternary system. Starting from an initial glass of approximately

[1] Received July 16, 1930.

[2] Otto Schott, Verh. des Vereins des Gewerbfleiss, p. 799 (1887)

the empirical composition $Na_2O \cdot CaO \cdot 6SiO_2$, in one series CaO is partially replaced by Al_2O_3; that is, this series is an excursion into the tetrahedron representing the four-component system, on the straight line joining the composition $Na_2O \cdot CaO \cdot 6SiO_2$ with the composition $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$, which is that of the mineral albite. These mixtures are essentially those whose viscosity-temperature relations have been determined by English[3] and discussed by Fulcher,[4] and, indeed, it was as the result of a discussion with Dr. Fulcher that this study of the effect of alumina was initiated. After ascertaining the effect of partially replacing CaO by Al_2O_3 as above described, a few additional experiments were made on a different plan. In these further experiments, alumina was added to the same Na_2O–CaO–SiO_2 glass, representing an excursion into the tetrahedron from the same initial point on the Na_2O–CaO–SiO_2 side toward the Al_2O_3 apex.

The methods used for the preparation of these mixtures and for their experimental study are those commonly used in this work, which have been described several times,[5] and need not be further discussed. The alumina was added in the form of a precipitated hydrate which contained less than 0.05% of Na_2O, an impurity of no importance in this study.

TABLE I

LIQUIDUS TEMPERATURES OF SOME Na_2O–CaO–Al_2O_3–SiO_2 GLASSES

No.	Na_2O	CaO	Al_2O_3	SiO_2	Temp. °C	Primary Phase
		(Initial glass $1.11Na_2O \cdot 0.95CaO \cdot 6SiO_2$)				
1	14.3	11.0		74.7	1075	Tridymite
			Series I			
2	14.1	9.8	2.1	74.0	997	Tridymite
3	14.1	9.3	2.9	73.7	1001	$Na_2O \cdot 3CaO \cdot 6SiO_2$
4	14.0	8.5	4.2	73.3	1004	$Na_2O \cdot 3CaO \cdot 6SiO_2$
5	13.8	6.2	8.0	72.0	1028	$Na_2O \cdot 3CaO \cdot 6SiO_2$
6	13.5	3.8	12.0	70.7	1008	$CaO \cdot SiO_2$
7	11.3	2.0	16.3	70.4	1055	$CaO \cdot SiO_2$
8	12.0	1.0	17.8	69.2	1090	$CaO \cdot SiO_2$
			Series II			
9	13.6	10.5	4.8	71.1	1079	$CaO \cdot SiO_2$
10	13.0	10.0	9.1	67.9	1156	$CaO \cdot SiO_2$

The experimental results are presented in two tables and one figure. Table I gives the composition of the glasses, their liquidus temperatures, and the primary phase. In Table II are assembled enough of the experimental data to substantiate Table I; usually many more experiments were made than are here recorded, but their inclusion would serve no useful purpose.

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[3] S. English, *Jour. Soc. Glass Tech.*, **9**, 83 (1925).

[4] G. S. Fulcher, *Jour. Amer. Chem. Soc.*, **8**, 789 (1925).

[5] G. W. Morey, p. 689, this issue.

Figure 1 shows the effect of Al_2O_3 on the liquidus temperature of the soda-lime glass. In curve I are plotted the results obtained by replacing CaO by Al_2O_3. There is a sharp drop in melting point, about 80° for 2% Al_2O_3, and the glass rapidly crosses the tridymite field, and enters the field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, indicating that in the solid model the boundary

TABLE II

QUENCHING DATA FOR THE GLASSES OF TABLE I

No.	Initial condition*	Temp. °C	Time	Final condition
1	(Interpolated from the ternary system $Na_2O{\cdot}SiO_2$–$CaO{\cdot}SiO_2$–SiO_2)			
			Series I	
2	G	852	17 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$; quartz
	G	915	2 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	915	2 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$; little quartz
	G	977	3 h	Glass; cristobalite
	X	977	3 h	Glass; little $Na_2O{\cdot}3CaO{\cdot}6SiO_2$; cristobalite
	G	994	20 h	Glass; tridymite
	X	1000	3 h	Glass
3	G	870	24 h	Glass; many excellent $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	1000	18 h	Glass; rare $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	1002	6 h	Glass
4	G	870	24 h	Glass; excellent $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	1002	6 h	Glass; rare $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	1006	6 h	Glass
5	G	1000	15 h	Glass; little $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	1027	1 h	Glass; rare $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	1030	1 h	Glass
6	G	850	16 h	Glass; $CaO{\cdot}SiO_2$
	G	980	15 h	Glass; rare $CaO{\cdot}SiO_2$
	G	1005	1 h	Glass; exceedingly rare $CaO{\cdot}SiO_2$
	X	1011	2 h	Glass
7	X, b	1048	3 h	Glass; little $CaO{\cdot}SiO_2$
	G	1048	15 h	Glass; rare $CaO{\cdot}SiO_2$
	X	1057	3 h	Glass
8	X, b	1080	16 h	Glass; few $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$
	X, b	1097	16 h	Glass
			Series II	
9	G	850	4 d	Glass; much good $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	G	1000	18 h	Glass; $Na_2O{\cdot}3CaO{\cdot}6SiO_2$
	X	1050	14 h	Glass; $CaO{\cdot}SiO_2$
	X	1075	1 h	Glass; few $CaO{\cdot}SiO_2$
	X	1081	1 h	Glass
10	G	1154	20 m	Glass; rare $CaO{\cdot}SiO_2$
	G	1159	30 m	Glass

* "G" indicates that the original charge was all glass; "X" that it was partially crystalline; "X, b" that it had been crystallized by heating with water in a bomb.

surface between tridymite and $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ is convex toward the SiO_2 apex of the component tetrahedron. On further replacing CaO by Al_2O_3, the liquid crosses the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ field, the liquidus curve showing a maximum temperature, and then enters the field of $CaO{\cdot}SiO_2$. At about 11% Al_2O_3, the decomposition of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ to $CaO{\cdot}SiO_2$ takes place at 1000°. This temperature is to be compared with the de-

composition temperature of the pure compound, 1060°, and its lowest decomposition temperature in the ternary system, at the invariant point tridymite–$Na_2O{\cdot}3CaO{\cdot}6SiO_2$–$CaO{\cdot}SiO_2$–liquid, at 1030°. There is a further lowering of 30° in the decomposition temperature as the result of the presence of Al_2O_3 in the liquid phase. On replacing more of the CaO by Al_2O_3, $CaO{\cdot}SiO_2$ remains the primary phase up to about 16.5% Al_2O_3, when the mineral albite, $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$, becomes primary

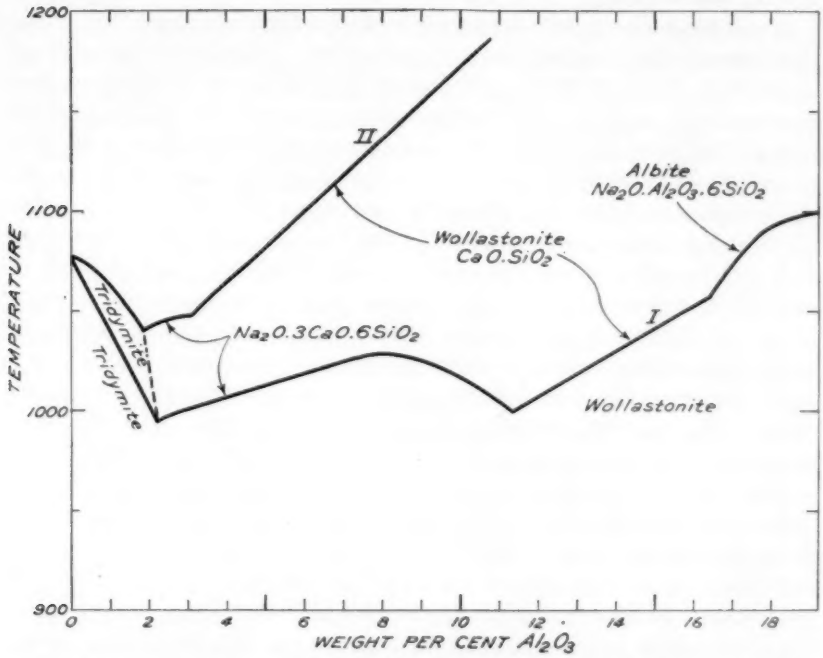

FIG. 1.—Liquidus temperatures of some Na_2O–CaO–Al_2O_3–SiO_2 glasses. Curve I shows the effect of replacing CaO by Al_2O_3 in a glass of the composition $1.11Na_2O$-$0.95CaO{\cdot}6SiO_2$. Curve II shows the effect of adding Al_2O_3 to the same glass.

phase, and the curve ends at the melting point of albite, 1100°.[6] The glasses in the first portion of this curve were not difficult to crystallize, although noticeably more difficult than the parent glass. This is to be expected from the lowering of temperature alone, and doubtless the increasing complexity of the solution has a similar effect. Glasses close to albite, however, crystallize with such difficulty that it was necessary first to heat them in bombs under hydrothermal conditions.[7] Small

[6] N. L. Bowen, *Amer. Jour. Sci.*, **35**, 577 (1913).

[7] G. W. Morey and C. N. Fenner, *Jour. Amer. Chem. Soc.*, **39**, 1173 (1917).

samples, of about 0.5 g., were wrapped in gold foil and heated over night at 525° and about 250 atmospheres of water pressure, under which conditions they crystallized readily. After the liquidus temperature was found, it was found possible to crystallize glass No. 7 in the dry way by heating just below the liquidus, but No. 8 could not be crystallized in 3 days under similar conditions. This is in harmony with the well-known fact that no one has yet been able to crystallize albite in the dry way without the aid of a flux.

It will be observed that the sequence of crystallization along this straight line through the tetrahedron representing the quaternary system Na_2O–CaO–Al_2O_3–SiO_2 indicates a complicated system of stability regions. Starting from an arbitrary composition approximating $Na_2O{\cdot}CaO{\cdot}6SiO_2$, and gradually replacing CaO by Al_2O_3 until the composition of the compound $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$ (albite) is reached, the primary phase is first the component, tridymite; then the compound, $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, from the limiting ternary system Na_2O–CaO–SiO_2; then the compound $CaO{\cdot}SiO_2$ (wollastonite), from the binary system CaO–SiO_2, representing one edge of the tetrahedron; and finally the ternary compound $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$ (albite), from the limiting ternary system Na_2O–Al_2O_3–SiO_2. In the three limiting ternary systems the phases whose fields adjoin that of one of the crystalline forms of SiO_2 are as follows: system Na_2O–CaO–SiO_2, $Na_2O{\cdot}2SiO_2$, $Na_2O{\cdot}3CaO{\cdot}6SiO_2$, and $CaO{\cdot}SiO_2$; system CaO–Al_2O_3–SiO_2, $CaO{\cdot}SiO_2$, the feldspar anorthite, $CaO{\cdot}Al_2O_3{\cdot}2SiO_2$, and $3Al_2O_3{\cdot}2SiO_2$; system Na_2O–Al_2O_3–SiO_2, $3Al_2O_3{\cdot}2SiO_2$, the feldspar albite, $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$, probably also $Na_2O{\cdot}Al_2O_3{\cdot}4SiO_2$, although this system has not yet been worked out, and $Na_2O{\cdot}2SiO_2$. If no new compounds are formed (and there is no indication from the results in this paper or from other unpublished results that any such are formed) the regions which border the SiO_2 region in the tetrahedron representing the quaternary system will be those of the compounds enumerated above, and it seems probable that $CaO{\cdot}SiO_2$ will be the adjacent phase over a large portion of the surface of contact. The results of the present study show that the stability region of $CaO{\cdot}SiO_2$ must be a large one, but it must be limited by the solid solution series formed between the two feldspars albite-anorthite.

Curve II of Fig. 1 shows the effect of addition of Al_2O_3 to the same $Na_2O{\cdot}CaO{\cdot}6SiO_2$ glass. The initial phase is tridymite, and the glass containing 4.8% Al_2O_3 formed $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ when crystallized at 1000°, but this decomposed to $CaO{\cdot}SiO_2$ before the liquidus was reached. The liquidus curve shows a small and less rapid melting point lowering on addition of Al_2O_3 than was found when the Al_2O_3 replaced CaO and a narrow field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$. $CaO{\cdot}SiO_2$ remained primary phase as far as the curve was followed, to 9.1% Al_2O_3 and 1156°, at which point the temperature is increasing rapidly. On further addition of Al_2O_3 the

liquid will probably enter the field of nephelite, $Na_2O \cdot Al_2O_3 \cdot 4SiO_2$, in its high temperature modification, carnegieite, but this is too extensive an excursion into the quaternary system to be of interest to glass technologists.

The experiments described in this paper have dealt with the effect of Al_2O_3 on one particular soda-lime glass, which was in the tridymite field. The effect obtained depended entirely upon the composition of the resulting glass. No generalization can be made as to the effect of Al_2O_3 on the devitrification of soda-lime glasses. We are here dealing with a four-component system, and a hasty generalization from insufficient data is sure to result in misleading conclusions. For example, compare the effect of the addition of 5% Al_2O_3 and the replacing of 5% CaO by Al_2O_3. Another illustration is the glass cited on p. 709 of a preceding paper on the devitrification of soda-lime-silica glasses,[8] in which 1.29% of Al_2O_3 added to a certain soda-lime glass raised the devitrification temperature. The glass was originally in the $CaO \cdot SiO_2$ field, and remained in the same field. It is probable that there was an initial lowering of the devitrification temperature, but it must be remembered that this is not a simple binary or even ternary system, but that on addition of Al_2O_3 the system becomes quaternary, and it is not possible to predict the shape and position of the isothermal surfaces in the tetrahedron. Only by experiment can the facts in regard to solubility and fusion relations be determined, and no hypotheses have yet been advanced which aid in predicting such relationships, or in solving the closely associated problem of whether or not there will be compound formation in a given set of components. For example, it was found that in the system Na_2O–CaO–SiO_2 there were no ternary disilicate compounds, only the known binary $Na_2O \cdot 2SiO_2$. It was a surprise to find in the system K_2O–CaO–SiO_2 three ternary disilicates, $4K_2O \cdot CaO \cdot 10SiO_2$, $2K_2O \cdot CaO \cdot 6SiO_2$, and $K_2O \cdot 2CaO \cdot 6SiO_2$, as well as the known $K_2O \cdot 2SiO_2$. There is no principle or law which will enable us to predict such relationships, and it is not possible to deduce the equilibrium relationships in a four-component system from a knowledge of the limiting three-component systems alone.

Commercial glasses of the soda-lime type frequently contain both MgO and Al_2O_3, and the best glass would be expected to have the relative proportions of these constituents so adjusted that the resulting glass is approximately on the boundary between SiO_2 and the adjoining phase. Such a condition is very nearly realized in a commercial glass, which glass had the composition: Na_2O, 15.90; K_2O, 0.52; MgO, 3.63; CaO, 5.13; $Al_2O_3 + Fe_2O_3$, 2.17; SiO_2, 72.23%. Quartz is the primary phase at the liquidus, 864°, and the boundary between quartz and $Na_2O \cdot 3CaO \cdot 6SiO_2$ is at 862°. The glass had been so proportioned that it was almost exactly

[8] G. W. Morey, p. 709, this issue.

on the quartz $Na_2O \cdot 3CaO \cdot 6SiO_2$ boundary, and its excellent qualities are in harmony with theoretical expectations. It differs but little in composition from the "electric light bulb glass" studied by Parmelee and Monack,[9] Glass No. 1 of their Table I, which had the composition: alkalis (by difference), 18.2%; MgO, 2.3; CaO, 5.1; $Al_2O_3 + Fe_2O_3$, 1.6; SiO_2, 72.9. They found that the glass did not show the least sign of devitrification after five thermal treatments (the details of which were not specified); but they state that at the glass plant where it was manufactured it was found possible to devitrify it by exposure at 1100° for three weeks. This glass will crystallize in 12 hours just below its liquidus, and the three weeks required at 1100° can only represent the time required to volatilize enough alkali to bring the glass composition to the 1100° isotherm. The devitrification of another glass containing both Al_2O_3 and MgO is described on p. 712 of the preceding paper on the devitrification of soda-lime-silica glasses to which reference has frequently been made.

Acknowledgment It is a pleasure to acknowledge my indebtedness to my colleagues Dr. N. L. Bowen and Dr. H. E. Merwin for their aid in the petrographic examinations.

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[9] C. W. Parmelee and A. J. Monack, *Jour. Soc. Glass Tech.*, **13**, 322 (1929).

FIRE CLAYS. SOME FUNDAMENTAL PROPERTIES AT SEVERAL TEMPERATURES[1]

By R. A. Heindl and W. L. Pendergast

ABSTRACT

This report gives the results obtained in the second phase of an extensive investigation of fireclay refractories. It is limited to the twenty-six representative clays included in that investigation. The geologic formation, chemical analyses, and pyrometric cone equivalents are given together with such properties of the clays fired at two widely different temperatures, as porosity, shrinkage, thermal expansion, moduli of elasticity and rupture, and plastic flow. Data are given to show the conversion of aluminous fire clays into mullite and cristobalite by firing at certain temperatures. At higher temperatures the cristobalite is converted to glass.

I. Introduction

A report[2] was published during the past year giving the results of an extended study of fireclay brick together with some preliminary test data of the fire clays used in their manufacture. That the present paper may contain all information obtained on the clays included in the present investigation, the data previously published will appear in this report together with the results obtained in recent studies. The chemical analyses of the clays, pyrometric cone equivalent values, and such physical properties as were determined after firing them at two widely different temperatures are given.

II. Materials and Identification

Twenty-six clays were furnished for this study by 12 manufacturers of refractory products. These clays were classed as follows: 7 flint, 4 semiflint, 12 plastic, and 3 miscellaneous. In addition three samples of quartz and sand were included.

All clays supplied by any one manufacturer were given one letter of the alphabet and also a number following this letter to identify the various clays furnished by each company. Furthermore, letter identification of the clays in each case corresponds with that assigned to the respective fireclay brick; for example, clays A-1 and A-2 are the clays supplied by the

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[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

This paper is the second of a series of reports which will be published on the general investigation of fireclay refractories being conducted by this Bureau.

Presented at the Annual Meeting, American Ceramic Society, Toronto, Ont., February, 1930 (Refractories Division). This paper has been published in the Bureau of Standards, *Journal of Research*.

[2] R. A. Heindl and W. L. Pendergast, "Progress Report on Investigation of Fireclay Brick and the Clays Used in Their Preparation," Bur. Stand., *Research Paper*, No. 114; also *Jour. Amer. Ceram. Soc.*, **12** [10], 640–75 (1929).

manufacturer of fireclay brick having key letter "A" as given in the preceding report.[2]

The approximate location of the mines where the clays are produced and the geologic formation as furnished by the companies coöperating in this study and supplemented in some cases by state geologists are given briefly in Table I.

TABLE I

TYPE OF CLAY, P.C.E., ORIGIN, AND GEOLOGIC FORMATION

Laboratory key	Type of clay	P.C.E.	Origin	Geologic age
A-1	Flint	32–33	Kentucky	Pottsville, Pennsylvanian formation
A-2	Plastic	32	"	" " "
B-1	Semiflint	32–33	Pennsylvania	Conglomerate vein, Pottsville, Pennsylvanian formation
B-2	Flint	33–34	"	Conglomerate vein, Pottsville, Pennsylvanian formation
B-3	Plastic	26	"	Middle Kittanning, Allegheny, Pennsylvanian formation
C-1	Flint	33–34	"	Mercer vein, Pottsville, Pennsylvanian formation
C-2	Plastic	28–29	"	Below Kittanning coal, Allegheny, Pennsylvanian formation
D-1	Semiflint	32	Missouri	Near base of Cherokee, Pennsylvanian formation
E-1	"	33	"	Near base of Cherokee, Pennsylvanian formation
G-1	Plastic	33	New Jersey	Sedimentary formation, Raritan, cretaceous formation
H-1	"	30	" "	Raritan, cretaceous formation
H-2	"	33	" "	" " "
H-3	Silica sand	32	" "	" " "
H-4	"	32	" "	" " "
H-5	"	33	" "	" " "
H-6	Plastic	31	" "	" " "
I-1	Semiflint	32–33	Kentucky	Pottsville, Pennsylvanian formation
I-2	Flint	34	"	" " "
I-3	Plastic	30	Ohio	Clarion clay, Allegheny, Pennsylvanian formation
K-1	Flint	34–35	Kentucky	Pottsville conglomerate, Pennsylvanian formation
K-2	Plastic	32	"	Pottsville conglomerate, Pennsylvanian formation
M-1	Flint	34–35	Pennsylvania	Pottsville conglomerate, Pennsylvanian formation
M-2	Plastic	32	"	Pottsville conglomerate, Pennsylvanian formation
P-1	Crushed quartz	33	California	
Q-1	Flint	33+	Missouri	Pennsylvanian formation
R-1	Plastic	30–31	California	Ione Eocene Sedimentaries, Ione formation
R-2	Kaolin	32–33	"	Residual deposit, Ione formation
R-3	Siliceous	33	"	Sedimentary clay, Ione formation
T-1	Plastic	30	Illinois	Beneath coal No. 1, Carbondale, Pennsylvanian formation and above St. Peter sandstone, Ordovician series

III. Preparation of Specimens

Two series of twenty-six different bodies were prepared. Each body contained only one raw clay and an equal amount of the same clay calcined

(grog). The grog in the one series of bodies was fired at approximately 1155°C for three hours (cone 4 down) and the other series contained grog fired at 1400°C (cone 14 down) for the same length of time. Specimens of the clay bodies for obtaining experimental data were also fired at 1155°C and 1400°C for three hours. Those fired at 1155°C contained the grog fired at 1155°C and those fired at 1400°C contained the grog fired at 1400°C. The grog was added as a part of the clay body in each

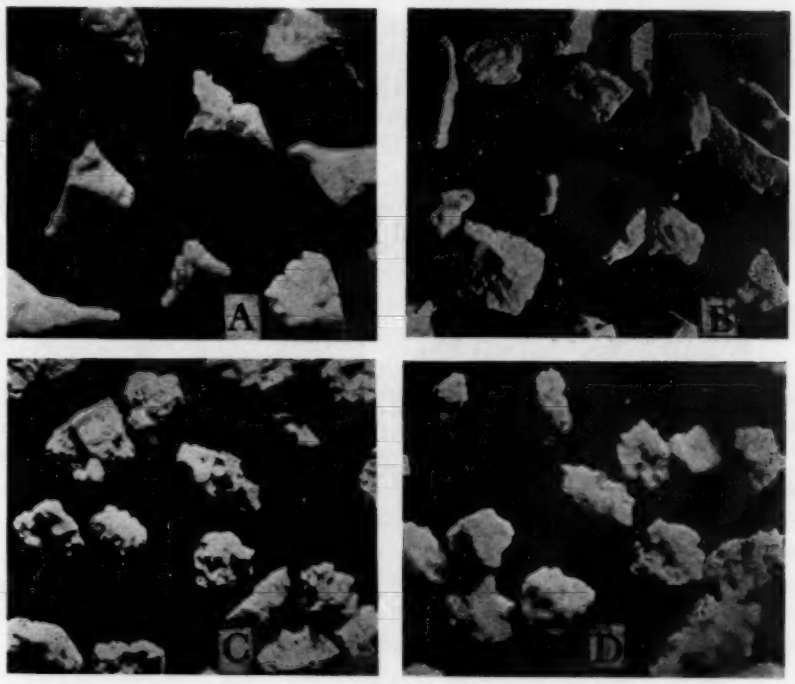

FIG. 1.—Photomicrograph (12 diam.) showing appearance of crushed grog prepared from four different fire clays. The letters (A, B, C, D) identify the grogs with the description of the four groups given in the text.

instance to reduce warping of the specimens during drying and firing. In order to insure uniform and comparable results, the clay in each case was ground to pass a 100-mesh sieve, and the grog was crushed and graded into three sizes. The grog used in the bodies consisted of the following combination of sizes:

Percentage of each size	Sieve number (U. S. Standard Series) Passed	Retained
50	20	40
25	40	100
25	100	Pan

An examination of the crushed grogs indicated that, according to fracture and appearance, there are four general types. The characteristics of the individual particles in some cases are not clearly defined, but most of the grogs could be classified according to the following groups:

(*a*) More or less regular in shape with comparatively sharp cleavage faces.
(*b*) More or less regular in shape with a tendency to have a platy fracture.
(*c*) Irregularly shaped without sharp fractures.
(*d*) Slightly rounded and somewhat soft.

A photomicrograph of a sample of grog representing each of the fore-

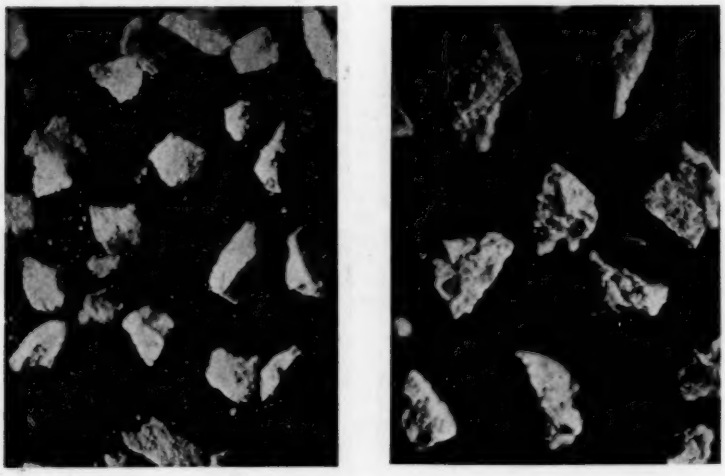

FIG. 2.—Photomicrograph (12 diam.) illustrating the effect of temperature on the shape and fracture of the grog particle. The grog on the left was fired at 1160°C and that on the right at 1400°C.

going groups is given in Fig. 1. The effect of temperature of firing on the fracture or cleavage and general appearance of a grog (R-1) is illustrated in the photomicrograph given in Fig. 2.

Eight specimens, 1 by 1 by 12 inches, and six specimens, 1 by 1 by 6 inches, were prepared from each of the 52 bodies. The 12-inch specimens were used for modulus of elasticity and transverse strength determinations and the 6-inch specimens for obtaining such properties as "tempering" or "conditioning" water, linear shrinkage, and dry strength. Data referred to in this report relative to absorption of grog, chemical analyses, pyrometric cone equivalent values, and mineralogical changes of clays fired at certain temperatures were obtained on the clays alone and data

on the other properties studied were obtained on the specimens containing equal parts of clay and grog.

IV. Methods of Testing

(1) Chemical Analyses In making the chemical analyses of the fire clays the procedure followed was, in general, the method of analysis for refractories described by Lundell and Hoffman.[3]

(2) Softening Point Test (Pyrometric Cone Equivalent) The softening point (P.C.E.) test was carried out according to the method approved by the Bureau and known as the A.S.T.M. standard method, serial designation C24–20.[4]

(3) Thermal Expansion Linear thermal expansions of the fire clays were determined by a direct method[5] on specimens measuring approximately 1 by 1 by 6 inches and which had been fired at 1155°C and at 1400°C. Determinations[6] were made from 20 to 1000°C.

(4) Modulus of Elasticity, Transverse Strength, and Plastic Flow A detailed description of the apparatus used in observing deflections of the specimens under various loads, the determination of the transverse strength (modulus of rupture), and the method for determining the load-deflection curves were published in the Third Progress Report of the Sagger Investigation.[7] The modulus of elasticity and modulus of rupture were determined at several temperatures, the former from the load-deflection curve and the latter using the load which broke the specimen.

The plastic flow at 1000°C of the various fireclay bodies was determined with the same apparatus as was used to determine the elasticity and breaking strength. The plastic flow of the material under any particular stress increment was considered as the "set" or difference between the deflection caused by the load and the recovery of the material on removal of this load. A detailed description of the method for determining this property was given in the Fourth Progress Report of the Sagger Investigation.[8]

(5) Supplementary Studies Linear drying shrinkage and dry strength were determined on the 6-inch specimens of

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[3] "Analysis of Bauxite and of Refractories of High Alumina Content," Bur. Stand., *Jour. Research*, **1** [Rept., No. 5], July (1928).

[4] Described in American Society for Testing Materials Standards for 1927, Part II, p. 151.

[5] For a description of the apparatus and method used, see *Jour. Amer. Ceram. Soc.*, **9** [9], 555–74 (1926).

[6] Room temperature was approximately 20°C during these experiments.

[7] *Jour. Amer. Ceram. Soc.*, **10** [7], 524–34 (1927).

[8] *Ibid.*, **10** [12], 995–1004 (1927).

the fireclay bodies after drying for several days at atmospheric temperature and finally at approximately 110°C for 24 hours and cooling in a desiccator. Linear fired shrinkage was obtained from specimens fired at 1155°C and 1400°C. These specimens were fired at the same time as those on which the other test data were determined.

The porosity was determined by treating the specimens in a vacuum for one hour at an absolute pressure of six millimeters of mercury. Distilled water was added while the specimens were still in vacuum and then boiled in vacuum for one and one-half hours. The specimens remained under water an additional 18 hours before being weighed.

V. Results

(1) Chemical Analyses

The chemical analyses of the materials investigated are given in Table II. A study of the data shows a wide variation in composition. Samples[9] H-3, H-4

TABLE II

CHEMICAL ANALYSES OF FIRE CLAYS

Laboratory key letter	Ignition loss (%)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	TiO_2 (%)	CaO (%)	MgO (%)	Total (%)
A-1	14.30	43.32	35.72	3.26	2.02	0.18	0.40	99.20
A-2	14.08	44.64	35.84	2.39	1.77	0.26	0.52	99.50
B-1	13.26	43.38	37.97	1.39	2.12		0.31	98.43
B-2	14.58	43.06	37.84	2.14	1.84	0.12	0.04	99.62
B-3	8.16	58.68	24.95	2.39	1.70	0.19	0.70	96.77
C-1	13.78	42.74	39.18	1.01	2.33		0.29	99.33
C-2	10.86	50.38	30.87	2.56	2.27	0.32	0.30	97.56
D-1	12.34	51.82	32.09	1.24	1.63		0.58	99.70
E-1	14.06	45.98	37.12	0.88	1.90	0.12	0.29	100.35
G-1	14.32	47.09	36.25	0.75	1.89	0.44	0.06	100.80
H-1	7.42	70.29	19.46	0.88	2.02	0.22	0.03	100.32
H-2	14.36	46.36	35.43	1.87	1.57	0.44	0.46	100.50
H-3	1.62	91.52	4.65	0.28	0.67	0.26	0.31	99.31
H-4	2.86	87.68	7.33	1.06	1.25	0.38	0.14	100.70
H-5	12.82	52.26	32.30	0.84	1.72	0.26	0.02	100.02
H-6	8.14	68.20	21.37	0.78	1.63	0.34	0.12	100.58
I-1	11.62	51.42	32.80	0.93	2.33		0.52	99.62
I-2	13.66	44.66	37.58	1.33	1.53	0.66	0.15	99.67
I-3	10.62	53.50	29.82	1.95	1.73	0.23	0.16	98.01
K-1	14.86	42.50	39.68	0.76	2.34		0.12	100.26
K-2	12.28	47.00	33.41	2.59	2.00	0.48	0.32	98.08
M-1	13.68	44.56	38.19	1.12	2.21	0.14	0.10	100.00
M-2	11.46	45.76	35.67	1.95	1.72	0.30	0.64	97.50
P-1	0.28	97.48	0.72	0.14	0.46	0.16	0.32	99.56
Q-1	13.32	42.32	39.63	0.84	1.81	0.68	0.50	99.10
R-1	12.06	52.78	29.90	2.37	1.07	0.04	1.20	99.42
R-2	14.66	44.46	37.31	1.13	2.76	0.20	0.12	100.64
R-3	7.22	72.78	18.94	0.65	0.61	0.23	0.14	100.57
T-1	10.92	60.26	25.28	1.62	1.28	0.38	0.16	99.90

[9] Complete test data on materials H-3, H-4, and P-1 were not obtained because they are largely silica.

and P-1 (Table II) are composed largely of silica. On the other hand, fire clays K-1, M-1, and Q-1 have a composition which closely approaches that of kaolin and contain very little free quartz.

(2) Tempering Water and Absorption of Grog The tempering water, that is, the percentage of water considered as desirable for securing proper molding consistency of the clay test specimens, is given in Table III. This information is given

TABLE III

TEMPERING WATER OF FIRECLAY BODIES AND ABSORPTION OF GROGS USED

Laboratory key	Tempering water; specimens containing grog fired to		Absorption; (per unit wt.) grog fired to	
	Cone 4	Cone 14	Cone 4	Cone 14
	(%)	(%)	(%)	(%)
A-1	17.3	16.1	11.6	9.4
A-2	18.1	16.0	10.6	0.9
B-1	18.1	19.1	12.3	7.4
B-2	18.9	17.4	16.7	1.1
B-3	17.3	16.1	7.8	12.0
C-1	21.4	16.7	16.0	11.6
C-2	16.5	16.7	6.0	8.7
D-1	18.1	14.5	7.7	3.6
E-1	18.8	14.9	13.8	2.6
G-1	23.9	16.9	26.3	6.3
H-1	20.9	19.7	20.7	18.1
H-2	22.0	19.3	9.6	2.6
H-5	24.8	18.4	20.9	6.8
H-6	20.1	19.7	20.0	17.5
I-1	18.1	14.8	13.0	6.8
I-2	18.1	14.8	14.6	6.7
I-3	18.7	15.1	11.5	1.1
K-1	20.5	16.6	17.6	11.1
K-2	19.4	17.2	7.9	0.4
M-1	20.8	18.1	19.7	11.7
M-2	19.2	17.2	22.3	6.9
Q-1	18.1	16.6	10.7	4.5
R-1	20.1	19.4	10.4	5.5
R-2	22.3	18.3	9.2	1.4
R-3	26.8	28.5	26.1	22.5
T-1	16.4	15.3	7.9	6.5

for those specimens containing grog fired to cone 4 as well as those containing grog fired to cone 14.

The percentage absorption of the grog fired at the two different temperatures is also given in Table III. The data on absorption show only two clays (B-3 and C-2) overfired at cone 14. It may be that other clays are overfired but this is not indicated by their appearance, and since no firings were made between cones 4 and 14, it is not known whether any of the clays reached an absorption lower than that given in the table. The smallest change in absorption was shown by the grog prepared from the highly siliceous clays.

The absorption of the grog apparently has little effect on the amount of tempering water used in preparing the specimens. Clay B-2 may be cited as a typical example. The percentage absorption decreased approximately 15.5 between the cone 4 and cone 14 firing, but the difference in percentage tempering water was only 1.5.

(3) Linear Shrinkage and Transverse Strength The linear shrinkage and strength after drying and the total linear shrinkage after firing of the specimens prepared with grog fired at the two different temperatures are given in Table IV.

TABLE IV

DRY AND FIRED SHRINKAGE, AND STRENGTH OF FIRE CLAYS

	Linear drying shrinkage		Total fired shrinkage		Dry strength (cross-breaking)	
	Specimens containing grog fired to					
Laboratory key	Cone 4 (%)	Cone 14 (%)	Cone 4 (%)	Cone 14 (%)	Cone 4 (lbs./in.²)	Cone 14 (lbs./in.²)
A-1	3.7	4.4	8.3	7.3	225	145
A-2	3.4	4.6	7.2	8.3	155	145
B-1	3.0	3.2	6.5	12.5	90	80
B-2	2.6	4.9	5.0	6.9	60	70
B-3	3.0	3.8	9.0	6.9	140	150
C-1	3.1	5.6	6.7	7.9	55	60
C-2	3.1	3.8	8.0	8.5	205	245
D-1	3.6	4.0	7.3	7.4	195	195
E-1	3.2	3.8	8.9	7.4	190	165
G-1	2.8	3.6	9.3	6.6	120	140
H-1	3.0	4.4	4.3	2.2	100	135
H-2	3.4	4.2	9.7	4.3	165	200
H-5	3.2	4.2	8.5	3.7	190	140
H-6	2.4	4.2	4.6	2.3	85	120
I-1	2.7	4.4	5.5	7.7	110	110
I-2	3.5	4.8	5.8	6.9	180	105
I-3	3.9	4.6	8.8	7.9	225	215
K-1	3.9	5.2	8.1	7.1	60	70
K-2	4.2	5.6	9.2	9.2	180	225
M-1	3.0	6.8	6.7	8.6	55	80
M-2	3.5	4.8	9.1	9.5	80	105
Q-1	4.2	4.8	8.7	9.3	180	180
R-1	4.2	5.4	9.8	9.7	180	375
R-2	2.5	3.8	13.1	7.5	85	125
R-3	3.5	6.0	7.4	7.9	35	70
T-1	3.4	5.4	5.3	6.3	400	295

The majority of specimens containing grog fired at the higher temperature show greater dry strength in comparison to those containing grog fired to the lower temperature, but the average values do not show a significant difference. The data on fired shrinkage do not indicate that any of the bodies are overfired at 1400°C. The bodies made up of clays H-1, H-5, and H-6, however, show a negative shrinkage (expansion) which is due to their high silica content and represents the conversion

of the quartz into cristobalite. As in the case of the porosity determinations the data obtained on fired shrinkage are quite misleading as an indication of whether the bodies are overfired because it is not known whether they reached their minimum shrinkage at some temperature before 1400°C. In the case of body B-3, an examination shows it to be overfired, although the shrinkage measurements do not so indicate.

(4) Porosity of Bodies The porosities of the fired specimens were determined on sections cut from the ruptured 12-inch bars on which data were obtained for moduli of elasticity and rupture computations. The results obtained on specimens fired at 1155°C are given in Table V and those fired at 1400°C in Table VI.

TABLE V

MODULUS OF ELASTICITY, TRANSVERSE STRENGTH, AND POROSITY OF FIRE CLAYS FIRED AT 1155°C FOR THREE HOURS

Laboratory key letter	Tested at 20°C Modulus of Rupture (lbs./sq. in.)	Tested at 20°C Modulus of Elasticity (1000 lbs./sq. in.)	Tested at 550°C Modulus of Rupture (lbs./sq. in.)	Tested at 550°C Modulus of Elasticity (1000 lbs./sq. in.)	Tested at 1000°C Modulus of Rupture (lbs./sq. in.)	Tested at 1000°C Modulus of Elasticity (1000 lbs./sq. in.)	Porosity (%)
A-1	2755	5530	2745	5275	3925	1040	23.9
A-2	2415	3840	2070	3785	2110	595	27.5
B-1	1690	3000	2055	4490	1950	505	28.5
B-2	480	835	580	1270	375	205	35.1
B-3	3370	7625	3555	7540	*	660	9.2
C-1	825	1515	790	1635	650	305	35.4
C-2	3220	7135	2775	5610	*	270	20.3
D-1	2435	3945	2415	4200	2940	945	25.5
E-1	3205	5115	3250	6260	3240	1610	21.2
G-1	1320	1890	2100	2525	2760	1040	33.3
H-1	565	584	795	1075	925	555	37.4
H-2	2010	3575	2655	4905	3290	1010	29.1
H-5	1100	1535	1640	2020	1610	905	35.5
H-6	465	410	675	840	740	415	37.2
I-1	1185	1725	1485	2785	2160	535	30.3
I-2	945	2000	1010	2080	850	295	32.7
I-3	2570	5005	3160	5385	4300	715	20.4
K-1	825	1650	820	1690	825	800	31.4
K-2	2710	6075	2385	5595	2770	400	24.7
M-1	870	1695	1040	1855	990	245	33.1
M-2	2795	5700	2690	5705	3665	465	24.7
Q-1	2235	4310	2500	4390	1480	620	27.3
R-1	2450	4730	2645	5675	4015	730	25.9
R-2	2075	4305	2335	4550	2390	1515	22.0
R-3	490	505	680	760	1100	590	41.2
T-1	1835	2595	1950	3515	3140	1180	28.0

* Specimen did not rupture.

TABLE VI

MODULUS OF ELASTICITY, TRANSVERSE STRENGTH, AND POROSITY OF FIRE CLAYS FIRED AT 1400°C FOR THREE HOURS

Laboratory key letter	Tested at 20°C Modulus of Rupture (lbs./sq. in.)	Tested at 20°C Modulus of Elasticity (1000 lbs./sq. in.)	Tested at 550°C Modulus of Rupture (lbs./sq. in.)	Tested at 550°C Modulus of Elasticity (1000 lbs./sq. in.)	Tested at 1000°C Modulus of Rupture (lbs./sq. in.)	Tested at 1000°C Modulus of Elasticity (1000 lbs./sq. in.)	Porosity (%)
A-1	2750	5800	2780	6180	3060	1930	24.7
A-2	2765	6570	2745	7415	3580	1425	19.7
B-1	2160	5060	2200	5320	2250	940	24.7
B-2	635	1485	725	1865	705	645	31.1
B-3	2285	6720	3240	8470	2750	300	0.7
C-1	1060	2290	2325	2745	1585	990	25.6
C-2	2630	8175	3000	8785	5150	850	11.1
D-1	3625	7420	2985	7960	3590	2655	16.8
E-1	2240	5820	3190	7015	2800	2410	21.8
G-1	1960	3090	2170	4025	2295	2160	27.4
H-1	670	795	1020	1730	1575	1480	34.0
H-2	2745	6980	2995	7220	3120	1740	24.7
H-5	2200	3310	2080	3645	2545	2285	28.0
H-6	695	695	880	1335	1430	1240	33.4
I-1	2205	3835	2735	6290	3060	2400	26.7
I-2	1500	2940	1625	3490	1850	985	27.7
I-3	3145	8830	2945	9425	3790	905	12.8
K-1	1155	2405	1155	2655	1030	1310	30.1
K-2	2990	7460	2480	7785	2970	1070	17.0
M-1	850	2040	830	2335	1140	790	30.2
M-2	2895	6435	2515	6325	3080	890	20.3
Q-1	2685	5885	2355	5870	3170	1020	22.0
R-1	3210	7655	3090	8960	3450	1375	17.2
R-2	1865	4065	1815	4300	2030	2300	30.6
R-3	475	465	575	875	750	670	37.9
T-1	2230	3590	2490	5345	3140	2790	25.7

The porosity values given represent the average of not less than three determinations.

(5) Pyrometric Cone Equivalents The P.C.E. values for all the materials included in this study are given in Table I, and with the exception of samples B-3 and C-3 (Pennsylvania plastic fire clays), have a P.C.E. value of 30 or above.

(6) Linear Thermal Expansion The linear thermal expansions of the 26 fireclay bodies were determined from atmospheric temperature to 1000°C. Determinations were made on the clays after having been fired at 1155°C and also at 1400°C. Check expansion determinations were made of all specimens, and the greatest variation in the data obtained on the same body was less than $\pm 2.5\%$.

The linear expansions for several different temperature ranges are

TABLE VII

COEFFICIENT OF LINEAR THERMAL EXPANSION OF FIRE CLAYS FIRED AT TWO DIFFERENT TEMPERATURES

Laboratory key letter	Average coefficient of expansion* for temperature range (°C) 100–200		500–600		20–1000		Classed in group†
	Clays fired at (°C) 1155	1400	1155	1400	1155	1400	
A-1	12.6	13.2	6.5	5.6	6.3	6.3	2
A-2	10.7	5.0	6.2	5.0	5.9	4.9	1
B-1	7.4	4.2	5.8	4.2	5.4	4.3	1
B-2	12.5	16.8	5.5	5.6	6.1	6.5	2
B-3	4.2	3.7	6.4	4.4	5.4	4.4	3
C-1	10.7	11.1	5.8	5.0	6.1	6.0	2
C-2	5.3	3.6	5.8	4.5	5.2	4.4	3
D-1	16.5	19.8	8.2	6.7	6.6	7.4	4
E-1	13.0	16.0	7.1	5.5	6.2	6.7	4
G-1	11.5	18.7	9.1	7.5	6.3	6.8	4
H-1	16.0	25.0	20.6	12.3	7.8	7.6	4
H-2	10.9	6.3	6.3	5.2	5.9	5.2	1
H-5	15.5	19.9	10.0	7.5	6.8	7.2	4
H-6	16.0	28.2	19.7	10.0	7.5	7.8	4
I-1	13.1	16.1	10.0	7.4	6.3	6.6	4
I-2	11.1	12.2	5.6	5.5	6.1	6.4	2
I-3	7.0	3.7	8.2	4.6	5.4	4.1	1
K-1	10.8	17.5	6.0	5.3	6.6	7.0	2
K-2	5.4	3.4	6.6	4.7	5.3	4.6	3
M-1	4.0	12.9	4.7	5.2	4.8	6.3	5
M-2	4.0	4.2	5.1	5.0	5.1	5.0	5
Q-1	5.3	4.6	6.1	5.1	5.6	5.2	3
R-1	9.6	6.2	6.2	4.4	5.8	4.9	1
R-2	12.0	17.6	6.2	5.9	6.7	6.8	2
R-3	8.0	21.0	12.7	12.0	5.4	7.0	4
T-1	21.3	30.0	11.9	5.6	8.1	8.0	4

* Values to be multiplied by 10^{-6}.

† These groups correspond to those referred to in Section 6, "Linear Thermal Expansion."

given in Table VII. These values are given to show how misleading it may be to accept the average coefficient of expansion from 20 to 1000°C as expressing the true thermal expansion behavior of the clay on heating, since it gives no indication of the volume changes which may occur over short temperature ranges. For example, the coefficient of expansion from 20 to 1000°C for clay B-2 gives no intimation that the material expands much more rapidly between 100°C and 200°C (Fig. 4) than between 200°C and 1000°C. The data given show the effect on the thermal expansion of firing the clays at two widely different temperatures and also how great the differences in this property may be over certain temperature ranges.

The various clays may be classified into five groups according to their

thermal expansion characteristics as determined by the free silica present either as quartz or in one or more of its allotropic modifications.

Group 1. Five bodies (A-2, B-1, H-2, I-3, and R-1), after being fired at 1155°C, show a high rate of expansion below 200°C and a somewhat less

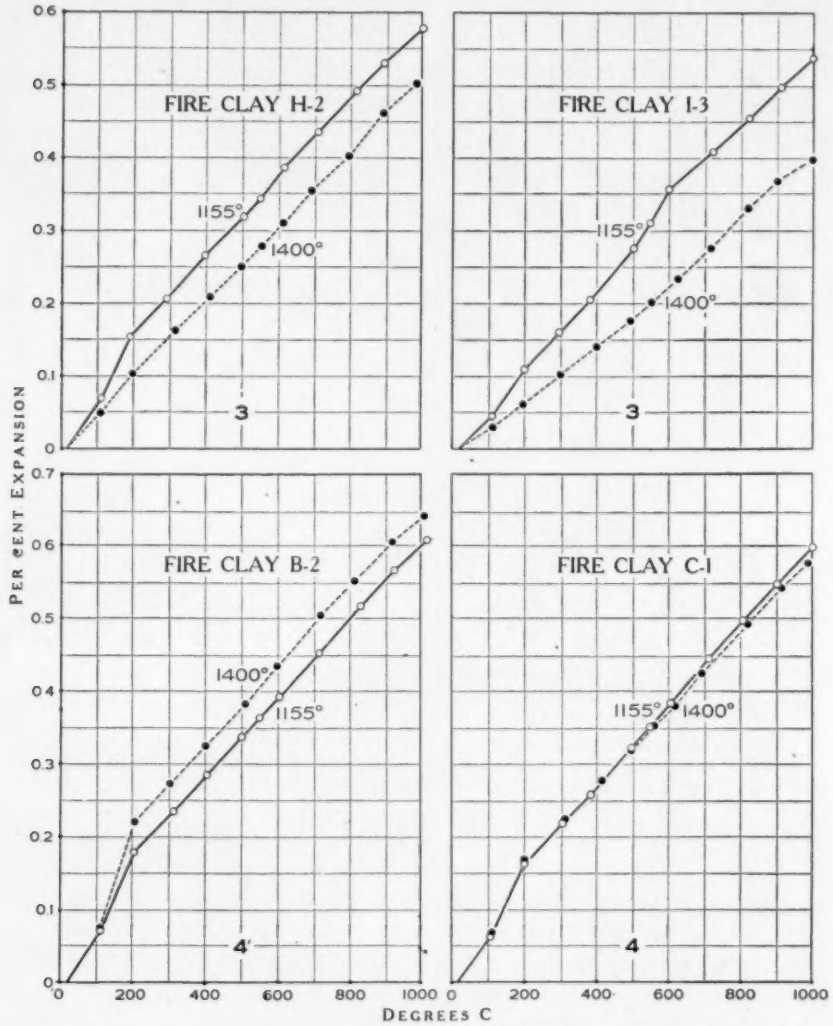

FIG. 3 (Upper).—The expansion characteristics of fire clays classed in Group 1. The curves show that the thermal expansion of these clays decreases by firing at the higher temperature.

FIG. 4.—The expansion characteristics of fire clays classed in Group 2. The curves for clay B-2 show that the expansion has increased after firing at the higher temperatures.

and more uniform rate between (approximately) 200°C and 1000°C. The data indicate that any free silica present is probably either in the form of tridymite or cristobalite. The expansion data obtained on these clays after firing at the higher temperature showed that the rate of expansion was practically uniform throughout the entire temperature range, indicating that the cristobalite had been converted to a highly siliceous glass. Body I-3, after the firing at 1155°C, in addition to the expansion characteristics described, shows also an increased rate of expansion between 500°C and 600°C, caused by the inversion of the alpha to beta quartz. After firing at 1400°C, this body shows a slight increase in the rate between (approximately) 750°C and 850°C. Examples of the expansion characteristics of this group are given in Fig. 3 and represent the data obtained on specimens of bodies H-2 and I-3.

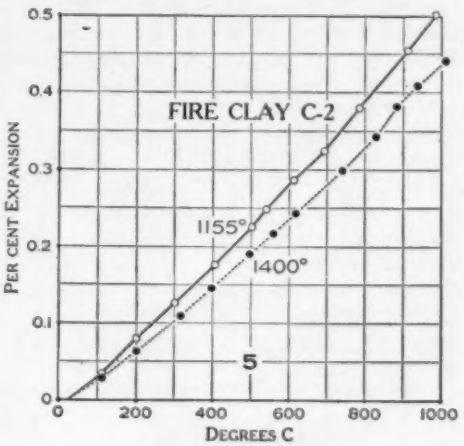

FIG. 5.—Thermal expansion characteristics of clays classed in Group 3 are shown by the data obtained on clay C-2.

Group 2. Six clays (B-2, I-2, K-1, R-2, A-1, and C-1) in this group are characterized by a high rate of expansion below 200°C occurring not only in test specimens fired at 1155°C but also after having been fired at 1400°C. The first four clays show a higher expansion after the 1400°C firing when compared with that obtained on the specimens fired at 1155°C. The increased total expansion is caused by the increased rate of expansion below 200°C, as shown by the greater inflection of the curve below that temperature.

The expansions of the other two clays, namely, A-1 and C-1, were practically unchanged by the firing at the higher temperature. The expansion data indicate that any free silica present in these fired clays occurs as either tridymite or cristobalite. The expansions are illustrated by the curves given in Fig. 4, representing data obtained on clays B-2 and C-1.

Group 3. Four clays (B-3, C-2, K-2, and Q-1) after the firings at both 1155°C and 1400°C have a comparatively uniform rate of expansion from room temperature to 1000°C, with the exception of a slight increase in the rate between (approximately) 750°C and 850°C of the clay specimens fired at 1400°C. The test pieces fired at the higher temperature show a considerably lower total expansion compared with those fired at the lower temperature. The expansion data obtained on clay C-2 illustrating this group are shown by the curves in Fig. 5.

Group 4. Nine clays (D-1, E-1, G-1, H-1, H-5, H-6, I-1, T-1, and R-3), after firing at 1155°C, have a high rate of expansion below 200°C and also between (approximately) 540°C and 600°C. These curves show that quartz, cristobalite, and tridymite are probably all present in the clay

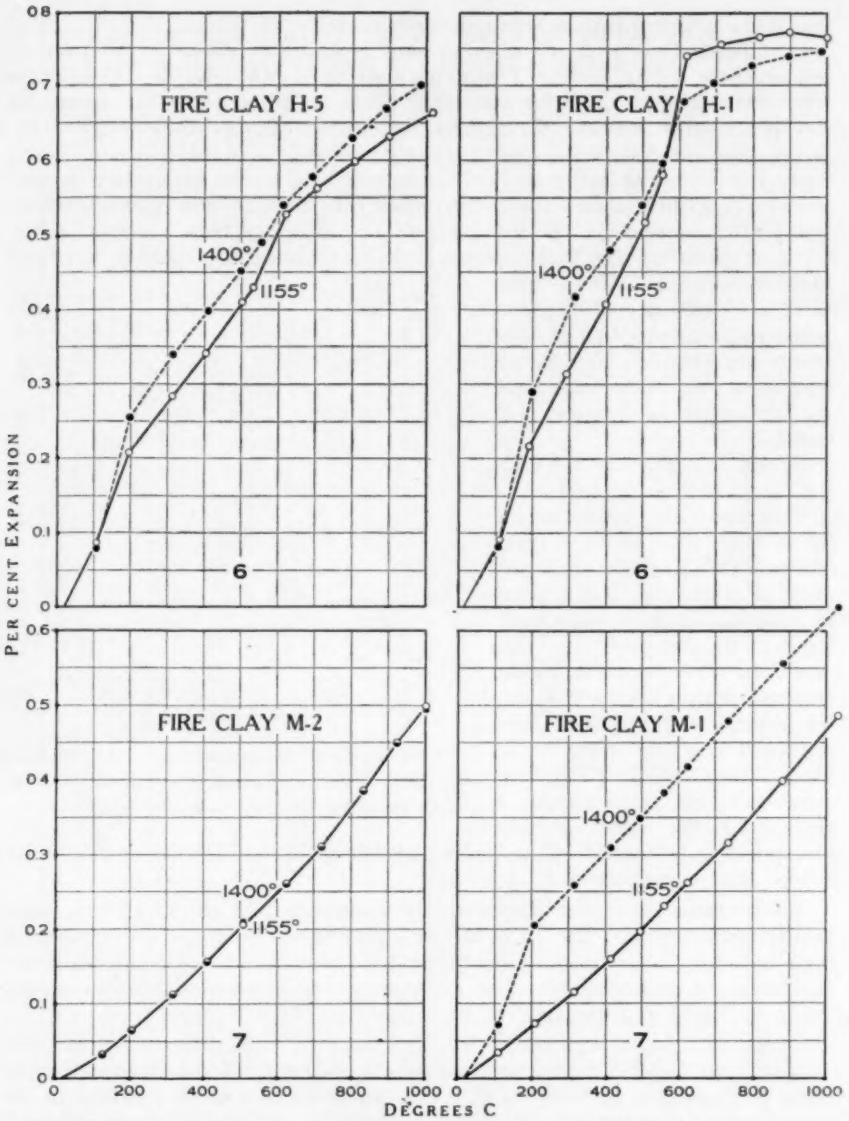

FIG. 6 (Upper).—The thermal expansion curves of clays H-5 and H-1 representative of clays of Group 4. The clays are of the highly siliceous type and as indicated by the curves are especially rich in cristobalite after firing at 1400°C.

FIG. 7.—The clays referred to in this figure have individual expansion characteristics and cannot be readily classed in any of the groups illustrated. Clay M-2 apparently has the same rate of expansion whether fired at 1155°C or 1400°C, whereas clay M-1 shows a decided change in this property.

bodies. After firing at 1400°C the inflection just below 600°C present in the expansion curves obtained after firing the specimens at 1155°C has practically disappeared or is greatly reduced. The total expansion, however, has increased in some cases due to the conversion of the quartz into cristobalite. Although R-3 may not strictly belong in this group because of the nature of its expansion after having been fired at 1155°C, it is included because the expansion shown after firing at 1400°C is very similar to that of the other clays. The expansion data of clays H-1 and H-5 are shown by the curves in Fig. 6. The continued high rate of expansion after firing at 1400°C is undoubtedly partially due to the high silica content and to the fact that the free quartz is present in comparatively coarse grains.[10]

Group 5. The two remaining bodies, M-2 and M-1, have individual expansion characteristics and cannot readily be classed in any of the foregoing groups. Body M-2 has a uniform rate of expansion from approximately 20 to 1000°C. It is the only clay body of all those tested which shows no change in the rate of expansion after having been fired at 1400°C in comparison with that obtained after the 1155°C firing. The expansion curves for this body are shown in the left section of Fig. 7.

The expansion data obtained on body M-1 fired at 1155°C indicate the rate to be uniform from 20 to 1000°C. The total expansion of the material after having been fired at 1400°C has increased decidedly over that obtained after having been fired at 1155°C. This change in total expansion is caused entirely by the high rate occurring below 200°C, due undoubtedly to the presence of either or both cristobalite and tridymite. The probable reaction resulting in the formation of this cristobalite and tridymite is discussed under Section 7. Curves for body M-1 are given on the right in Fig. 7.

(7) Effect of Temperature of Firing on Mineralogical Composition of Fire Clays

It has been known for some time that mullite and free silica develop during the firing of clays in certain temperature ranges and that fluxes bear an important relation to that development. As a result of the present study it is possible to show how the linear thermal expansion is directly affected by the formation of mullite and the development of free silica accompanying it.

Five clays, namely, B-2, C-1, I-2, K-1, and M-1, whose alumina-silica ratio closely approaches that of kaolin and which contain little, if any, free quartz were found to be especially sensitive to heat treatment. Firing at certain temperatures caused marked changes in their mineralogical composition. This is indicated by linear thermal expansion measurements and to a lesser extent by petrographic examination. There are other clays included in this investigation whose compositions are probably affected in the same manner as the above five clays, but this particular phase of the study was limited to these five clays.

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[10] Otto Bartsch calls attention to the effect of firing temperature and firing time on transformation of quartz of varying grain size in his paper "Expansion Behavior of Some Quartz Containing Clays," *Glastech. Ber.*, 7 [2], 48–61 (1929).

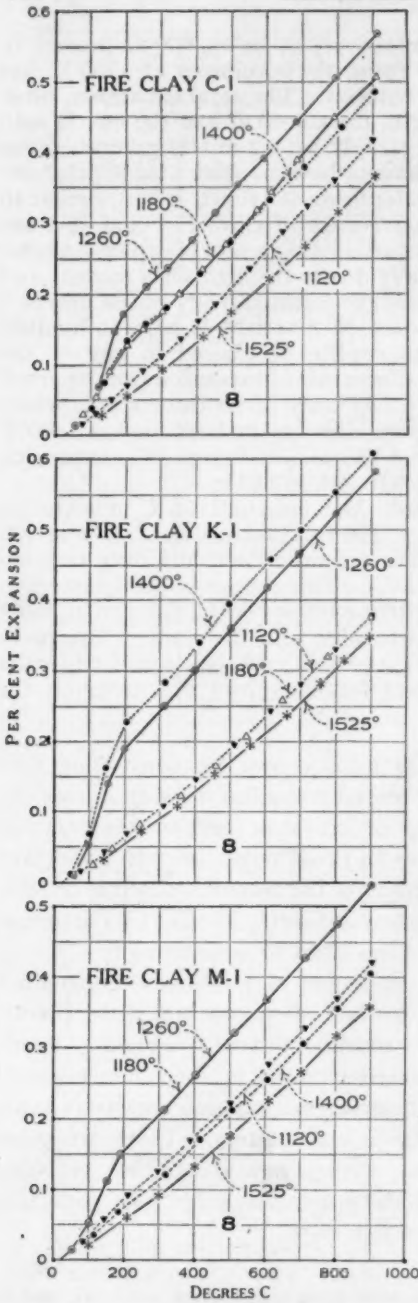

FIG. 8.—Linear thermal expansions of aluminous fire clays after firing at each of five different temperatures. The development of cristobalite, mullite, and glass at various stages is indicated.

The formation of mullite from clay may be expressed as follows:

$$3(Al_2O_3 \cdot 2SiO_2) + \text{heat} = 3Al_2O_3 \cdot 2SiO_2 + 4SiO_2$$

Thermal expansion measurements were made after firing the clays at progressively increasing temperatures to show how the change in composition proceeds in accordance with the above equation. Petrographic examinations[11] were made of the raw clays and also after each firing treatment.

Expansion measurements from 20 to 900°C were made with the interferometer[12] on specimens of clays C-1, K-1, and M-1 fired to cone 5 half down (1120°C); cone 6 (1180°C); cone 11 (approximately 1260°C); cone 15 half down (1400°C); and cone 19 (1525°C). Curves showing the data obtained on these three clays are given in Fig. 8. Measurements were made on specimens of clays B-2 and I-2 only after firing at three temperatures and data regarding them are not included.

The expansion curves (Fig. 8) obtained on each of the clays, after firing at 1120°C, show the rate of expansion to be uniform from 20 to 900°C. Expansion measurements made on the clays after firing at 1525°C also show the rate of expansion to be uniform, but slightly below that obtained on specimens fired at the lower temperature in the case of

[11] Petrographic examinations made by H. Insley.

[12] Described in Bur. Stand., *Sci. Paper*, No. 485.

C-1 and K-1, but decidedly lower in the case of M-1, as may be seen from the curves in Fig. 8. The changes occurring in both the mineralogical composition and thermal expansion characteristics of the materials when fired at temperatures between 1120°C and 1525°C are quite decided, as indicated both by the results of the petrographic examination and by the expansion curves given in Fig. 8. A description of these changes follows:

Clay C-1: Fired at 1120°C. Rate of expansion uniform from 20 to 900°C. The petrographic examination shows the clay to be wholly converted to an isotropic, probably amorphous material, with a mean index of refraction of 1.57. This serves as a matrix for minute particles which are birefringent and have a very different index from the amorphous material.

Fired at 1180°C. The total expansion after firing at 1180°C has increased appreciably from 20 to 200°C when compared with that obtained after firing at 1120°C. This change in expansion is caused by the partial formation of mullite from the clay with the liberation of silica in accordance with the above equation. The change in the rate of expansion below 200°C indicates that the silica which is set free (excess silica) is probably present as cristobalite.

Fired at 1260°C. The maximum total expansion both at 200°C and 900°C was obtained after firing at 1260°C. At 200°C the total expansion has increased over 150% and at 900°C about 35% when compared with that obtained at the same temperatures on the specimen fired at 1120°C. From the data obtained it would appear that the formation of mullite from the clay is about complete.

Fired at 1400°C. A decided decrease in the expansion between 20°C and 200°C has taken place. The curve obtained practically coincides with that obtained after firing the clay at 1180°C. This indicates that the crystalline silica (cristobalite) has partially been converted to a highly siliceous glass. The petrographic examination shows only two substances present:

(*a*) Minute needles of mullite with a maximum length of about 0.012 mm. and a maximum width of about 0.002 mm.

(*b*) A material which forms a matrix for the mullite and has a much lower index.

The measured mean index of refraction of this fired clay was found to be 1.582 ±0.003. By calculation the mean index should be 1.579 if the grains were composed of mullite and cristobalite and 1.565 if the grains were composed of mullite and glass.

Fired at 1525°C. The rate of expansion of the clay is again uniform throughout the entire range studied and the total expansion is appreciably lower than that obtained after firing at 1120°C, which was the lowest of any of the previous measurements. The petrographic examination shows this fired clay to be composed entirely of mullite and a glassy matrix material. The mullite needles are somewhat larger (about 0.004 mm. in width) than those found after that firing at 1400°C. Mean index measurements on grains composed of mullite and the matrix material gave uncertain results. The glassy matrix material was too small in quantity to

identify definitely; however, the thermal expansion measurements would indicate that the cristobalite has been wholly converted to glass.

Clay K-1: Fired at 1120°C. The petrographic examination showed an amorphous matrix in which are embedded minute particles with a greatly different index and generally high birefringence. The mean index of the grains is about 1.57. The rate of expansion is uniform throughout the entire range measured.

Fired at 1180°C. The expansion curve coincides with that obtained after firing the clay at 1120°C. This would indicate that the formation of mullite from the clay does not occur at as low a temperature as in the case either of clay C-1 or M-1, although there is very little difference in the P.C.E. value of the three clays.

Fired at 1260°C. The rate of expansion below 200°C and the total expansion at both 200°C and 900°C has increased greatly in comparison with that obtained after firing at either 1120°C or 1180°C. It would appear that the formation of mullite from the clay proceeds at a very rapid rate when once the proper temperature is reached.

Fired at 1400°C. The total expansion both at 200°C and 900°C has reached its maximum after firing the clay at this temperature. At 200°C the total expansion is over 260% greater and at 900°C, over 60% greater than that obtained at these temperatures on the specimens fired at 1120°C. The petrographic examination shows this fired clay to consist of mullite and a matrix material too small in quantity to identify. An occasional small grain of quartz was observed. The thermal expansion shows that the liberated silica (cristobalite) appeared in greatest quantity during this firing.

Fired at 1525°C. The rate of expansion is again uniform throughout the entire range measured and the total expansion is lower than that obtained on this clay after firing at any of the other temperatures. The inflection in the curve caused by the expansion of the cristobalite has entirely disappeared. The petrographic examination shows the fired clay to consist of small mullite crystals in a matrix material, the index of which it is impossible to determine. The variations which may occur in the thermal expansion of fire clays, depending on the changes in mineralogical composition caused by firing at different temperatures are shown to unusually good advantage by the data obtained on this clay.

Clay M-1: Fired at 1120°C. The petrographic examination shows that the material is composed largely of an isotropic matrix which has a slightly fibrous texture. Minute inclusions, with an index of refraction very different from the matrix and showing high birefringence, are present. The mean index of the grains is about 1.565. The fibrous texture may be an inheritance from the original platy structure of the clay. The rate of expansion is uniform from 20 to 900°C.

Fired at 1180°C and 1260°C. The maximum expansion both at 200°C and 900°C was reached after firing at 1180°C and is identical with that obtained after firing the clay at 1260°C.

Fired at 1400°C. The inflection in the expansion curve at 200°C has entirely disappeared, which is in contrast with clays C-1 and K-1. The petrographic examination shows that the grains are composed only of mullite distributed uniformly throughout a matrix material. Mean index of the grains is about 1.58. The formation of mullite from the clay apparently

proceeds at a very rapid rate and the reaction referred to at the beginning of this section is apparently completed much sooner than in case of either clay C-1 or K-1.

Fired at 1525°C. The rate of expansion is uniform and the total expansion is lower than that obtained on the clay after the firings at any other temperature. The petrographic examination shows the grains to be composed only of mullite and a matrix material. The mullite needles are somewhat larger and better developed than in the preceding firing. It is impossible to determine the index of the matrix material accurately, but it appears to be about 1.50. It would appear that the crystalline silica (cristobalite) has been converted to glass.

The data obtained in this study show that these clays have a comparatively straight-line expansion when fired at 1120°C and are still essentially the same in microscopic appearance as the unfired clay. As the temperature of firing is increased, both the expansion and mineralogical composition change and development of mullite is noted. The petrographic examination of the raw clays showed little or no free quartz present. Therefore, the uncombined silica indicated by the high rate of expansion below 200°C for specimens fired at certain temperatures above 1120°C (Example: clay K-1, 1260°C fire) is believed to have been set free due to the formation of mullite from the clay matter. This excess silica forms, according to expansion observations, as cristobalite with possibly some tridymite and gradually changes at increased temperatures to a highly siliceous glass. The petrographic examination shows the mullite needles to be embedded in a glassy matrix which is not present in sufficient quantity to be definitely identified.

The reaction involving the formation of mullite from clay is especially interesting since it occurs within the range of temperature used in the firing of fireclay refractories. It is obvious that it may reach varying stages of completion in the refractories placed in different parts in the kiln. It follows, therefore, that the properties of the refractories taken from different parts of a kiln setting must necessarily be different, depending on the state of progress of the reaction when arrested.

(8) Moduli of Elasticity and Transverse Strength

The stress (load) strain (deformation) curves, from which the moduli of elasticity were computed, were determined on specimens approximately 1 inch in cross-section and 12 inches long. They were placed across a 10-inch span and loaded at the center.

The transverse strengths (moduli of rupture) of the various fire clays were computed from the loads required to break the specimens on which the load-deflection curves were determined.

The two extreme types of rupture which occurred in the testing of these clay specimens are shown in Fig. 9. The upper specimen (1) shows the break to be practically perpendicular to the base of the specimen

and is associated with bodies which are open firing. The specimen (2) just below this shows a type of break which has a tendency to result in a partially curved surface. Such ruptures occur in dense or highly vitrified bodies.

Determinations of moduli of elasticity and rupture were made on specimens of the fireclay bodies after having been fired at 1155°C and also at 1400°C. Data were obtained at room temperature, 550°C and 1000°C, and the results for the clays fired at the lower temperature are given in Table V and those fired at the higher temperature in Table VI. All values, with the exception of those determined at 1000°C, represent

FIG. 9.—Showing the two most prevalent types of rupture occurring in specimens of clays tested for modulus of elasticity and rupture.

the average of not less than two determinations, either value making up this average varying less than 10% from that average.

Comparing the results obtained at 20°C on specimens fired at 1155°C (Table V) with those fired at 1400°C (Table VI) the following information is obtained:

(*a*) With four exceptions, B-3, C-2, R-2, and R-3, which show decreases, the bodies show greater transverse strengths after the firing at the higher temperature. Although several of the clays show little change, the majority show decided increases ranging to 100%.

(*b*) With two exceptions, B-3 and R-3, the moduli of elasticity of the bodies are greater after firing at 1400°C than after firing at 1155°C. The increases range from a minimum of approximately 5% to a maximum of 120%.

The results from the tests made at 550°C and 1000°C are relatively the same as those obtained at 20°.

A comparison of the values obtained at 550°C with those obtained at 20°C of specimens fired at either 1155° or 1400°C shows, in general, that the percentage increase in moduli of elasticity and rupture is greater in highly siliceous bodies than in aluminous bodies.

(9) Plastic Flow Deflection readings resulting from the plastic flow measured at 1000° C of the twenty-six fireclay bodies fired at 1155°C and 1400°C are given in Table VIII which is divided into

TABLE VIII

PLASTIC FLOW DATA MEASURED AT 1000°C ON FIRE CLAYS

Clay no.	Clays fired at 1155°C: Av. deflection readings (in.) at 5-min. intervals on 1-x 1-x 12-in. specimens using a 10-in. span: During 1 hr. stress approx. 60 lbs./sq. in.	Clays fired at 1155°C: Av. deflection readings (in.) at 5-min. intervals on 1-x 1-x 12-in. specimens using a 10-in. span: During ½ hr. stress approx. 120 lbs./sq. in.	Clays fired at 1155°C: Total plastic deflection (in.) (from plastic flow curves) at 1000°C with stress approx. 360 lbs./sq. in.	Clays fired at 1400°C: Av. deflection readings (in.) taken at 5-min. intervals on 1-x 1- x 12-in. specimens using a 10-inch span: During 1 hr. stress approx. 60 lbs./sq. in.	Clays fired at 1400°C: Av. deflection readings (in.) taken at 5-min. intervals on 1-x 1- x 12-in. specimens using a 10-inch span: During ½ hr. stress approx. 120 lbs./sq. in.	Clays fired at 1400°C: Total plastic deflection, in inches, with stress approximately 360 lbs./sq. in. (taken from plastic flow curves. See footnote No. 13)
A-1	<0.0001	0.0001	0.0025	<0.0001	<0.0001	0.0003
A-2	0.0002	0.0004	0.0048	<0.0001	<0.0001	0.0004
B-1	0.0003	0.0004	0.0063	<0.0001	<0.0001	0.0007
B-2	0.0005	0.0013	0.0208	<0.0001	0.0001	0.0013
B-3	0.0053	0.0138	0.1230	0.0005	0.0005	0.0080
C-1	0.0004	0.0020	0.0156	<0.0001	0.0001	0.0010
C-2	0.0007	0.0014	0.0062	<0.0001	0.0001	0.0008
D-1	0.0003	0.0004	0.0018	<0.0001	<0.0001	0.0003
E-1	0.0001	0.0002	0.0018	0.0001		0.0003
G-1	0.0001	0.0002	0.0018	<0.0001	<0.0001	0.0006
H-1	0.0001	0.0003	0.0060	<0.0001	<0.0001	0.0004
H-2	0.0001	0.0001	0.0022	0.0001	0.0001	0.0009
H-5	<0.0001	0.0002	0.0020	<0.0001	<0.0001	0.0002
H-6	0.0003	0.0004	0.0050	0.0001	0.0001	0.0004
I-1	0.0002	0.0003	0.0048	<0.0001	<0.0001	0.0002
I-2	0.0005	0.0011	0.0275	<0.0001	<0.0001	0.0005
I-3		0.0004	0.0030	0.0002	0.0002	0.0018
K-1	0.0001	0.0003	0.0044	<0.0001	<0.0001	0.0010
K-2	0.0005	0.0006	0.0072	<0.0001	0.0004	0.0003
M-1	0.0004	0.0010	0.0184	<0.0001	<0.0001	0.0011
M-2	0.0003	0.0004	0.0056	<0.0001	<0.0001	0.0006
Q-1	0.0002	0.0008	0.0036	<0.0001	<0.0001	0.0007
R-1	<0.0001	0.0003	0.0032	0.0001	0.0001	0.0010
R-2	<0.0001	0.0002	0.0030	<0.0001	0.0001	0.0003
R-3	0.0002	0.0002	0.0036	<0.0001	<0.0001	0.0017
T-1	<0.0001	0.0002	0.0016	<0.0001	<0.0001	0.0004

two major parts. The left section presents data obtained on specimens of clay fired at 1155°C and the right section, those fired at 1400°C. The first two columns in each section represent the average of increments obtained every five minutes after the first five minutes for one hour when using a stress of approximately 60 lbs./in.^{2} and a second test for a one-half hour period when using a stress of approximately 120 lbs./in.^{2} The load was applied midspan of the 1- by 1- by 12-inch specimens on a 10-inch span.

The data obtained with these loads applied to clays B-3 and M-1, which represent two clays of widely different plastic flow properties, are shown in Fig. 10. These curves illustrate the effect of temperature of firing on the plastic flow as well as the relative amounts which take place after the first five-minute interval. A large part of the deflection

taking place during the first time-interval represents the elastic properties of the clay. In the case of clay M-1, fired at 1400°C, there is very little plastic flow after the initial time increment. This is in contrast with clay B-3 which shows continued flow to the final reading.

The values given in the third column of each section of Table VIII represent the total plastic deflection in inches of the various clays under a stress of approximately 360 lbs./in.^{2} The values were taken from the plastic flow curves described as follows in the "Progress Report on Investigation of Fireclay Brick and the Clays Used in Their Preparation":[13]

Typical load-deflection curves as obtained at 1000°C on a specimen cut from fireclay brick are shown in Figure 13. The upper curve shows the plastic flow of the material under these same loads and the middle curve of the elastic properties. The elastic recovery of the material was considered as the difference between the total deflection caused by the load and the "set" ("representing plastic flow") of the material on removal of this load.

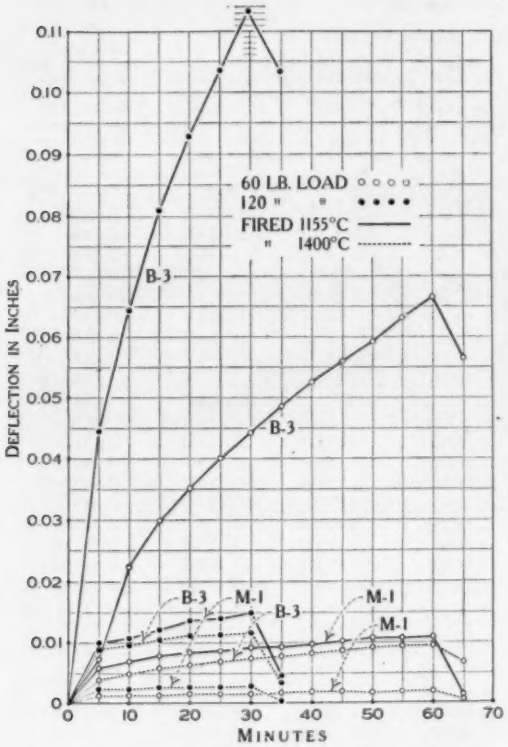

FIG. 10.—Time-deflection curves obtained at 1000°C on clays B-3 and M-1. Constant loads of approximately 60 and 120 lbs./in.^{2} were applied for periods of one hour and one-half hour, respectively. As indicated by the curve the final reading was taken after the removal of the load.

The results of this study may be summarized as follows:

(1) The plastic flow of these clays fired at either 1155°C or 1400°C when loads of 60 lbs./in.^{2} and 120 lbs./in.^{2} are applied is very small.

(2) The values of plastic deflection are decidedly different for the various clays when loads greater than those referred to under (1) are used. This is indicated by the results given in Table VIII when a load of 360 lbs./in.^{2} is used and is especially apparent in the clays fired at 1155°C.

(3) The plastic deflections of the clays fired at 1400°C are decidedly lower than those of the same clays fired at 1155°C.

[13] Bur. Stand., *Research Paper*, No. 114; also *Jour. Amer. Ceram. Soc.*, **12** [10], 640–75 (1929).

(4) The highly siliceous clays[14] show the least plastic deflection after firing either at 1155°C or 1400°C. Next in order are the siliceous clays which are followed by the aluminous.

(5) The plastic deflection of the clays after firing at 1400°C is not greatly different. It would appear that the development of the crystalline phase in the aluminous clays is decidedly advantageous in decreasing their plastic flow.

Figure 11 shows an untested specimen (3) in contrast with one (4) that has been tested. Specimen 4, which is prepared from clay B-3, deflected beyond the capacity of the testing apparatus without rupturing and represents an extreme case.

(10) **Grouping of Clays.** With the exception of the three samples of silica or quartz (H-3, H-4, and P-1), all are plotted according to chemical

FIG. 11.—The lower specimen illustrates a fire clay having a very high plastic flow under load at 1000°C. Just above this is an untested specimen prepared from clay E-1.

analyses on the small section of a triaxial diagram shown in Figure 12. The values given for silica, alumina, and flux are computed to a water-free basis. Since all of the compositions fall in a small section of the diagram, it was considered desirable to show only that section on an enlarged scale. The lower left apex of the section represents 55% alumina, the apex at the right, 35% flux, and that at the top, 80% silica. The position in the diagram indicated by the cross within the circle represents the composition of a washed North Carolina kaolin and is given simply to show how the various clays compare in composition to a typical kaolin.

The clays have been divided into three groups, as indicated by the dashed lines. The maximum percentage of mullite, which may theoretically be obtained from a clay of given composition fired under favorable conditions for such development, was computed from the chemical analysis (water-free basis). These values are only approximate since, according to the nature of the system, some of the alumina must necessarily have gone

[14] Arbitrarily considered as those containing more than 60% silica (water-free basis).

into solution with the glass which is present. The line *YY'* was so placed as to include those clays (Group A) having less than 40% "free silica" after the formation of mullite. The area between lines *YY'* and *ZZ'* includes those (Group B) which theoretically contain between 40% and 50% "free silica" and those falling above line *ZZ'* (Group C) contain over 50%. Important properties of the three groups are indicated by the values given in the following table:

Values Show Percentage Change in Properties for Specimens Fired at 1400°C as Compared with Those Fired at 1155°C and Are Given as Average Percentages for Each Group.

	Porosity	Modulus of rupture* at 20°C	Modulus of elasticity at 20°C	Modulus of elasticity at 1000°C
Group A (less than 40%† free SiO_2)	−10.8	30.8	44.4	133.3
Group B (between 40% and 50% free SiO_2)	−30.6	50.9	71.6	180.7
Group C‡	−8.8	28.0	37.9	120.3

* Determinations for this purpose made on a 4-in. span because of greater number available.

† Refers to "free silica" which could theoretically be present after the formation of mullite.

‡ Clay B-3 not considered in group average because of its low P.C.E. value..

These averages indicate that the clays classed in Groups A and C have properties which are probably more desirable in clays for the manufacture of refractories than those classed in Group B. The percentage change in porosity would indicate that the firing range of clays in Group B is shorter than that of the clays included in the other groups. The percentage change in values for moduli of elasticity, both at 20°C and 1000°C, and moduli of rupture show that the percentage of glass in the clays of Group B is probably greater or formed more rapidly at the higher temperature of firing than in Groups A and C. The average total linear thermal expansion (Table VII) at 1000°C of clays in Group C, however, is almost 30% greater than that of either of the other two groups. The high expansion of the clays in this group (see expansion curve for clay H-1, Fig. 6) is caused by the high percentage of quartz or silica they contain. In general, therefore, the clays in Group A have properties which are most desirable in refractory products.

VI. Summary

Twenty-six fire clays and three samples of quartz and silica sand were furnished for this study by manufacturers of fireclay refractories. Information obtained on these clays included: (1) chemical analyses; (2) tempering water and absorption of grog; (3) linear shrinkage and unfired strength; (4) porosity of fired clays; (5) pyrometric cone equivalents; (6) linear thermal expansion; and (7) the effect of temperature

of firing on the mineralogical composition of fire clays; (8) moduli of elasticity and transverse strength of the fired clays; (9) plastic flow.

The chemical analyses of the clays show them to range from the aluminous type to the highly siliceous. The results of such determinations as absorption, porosity, shrinkage, and pyrometric cone equivalent values are given in a series of tables. The approximate location of the mines

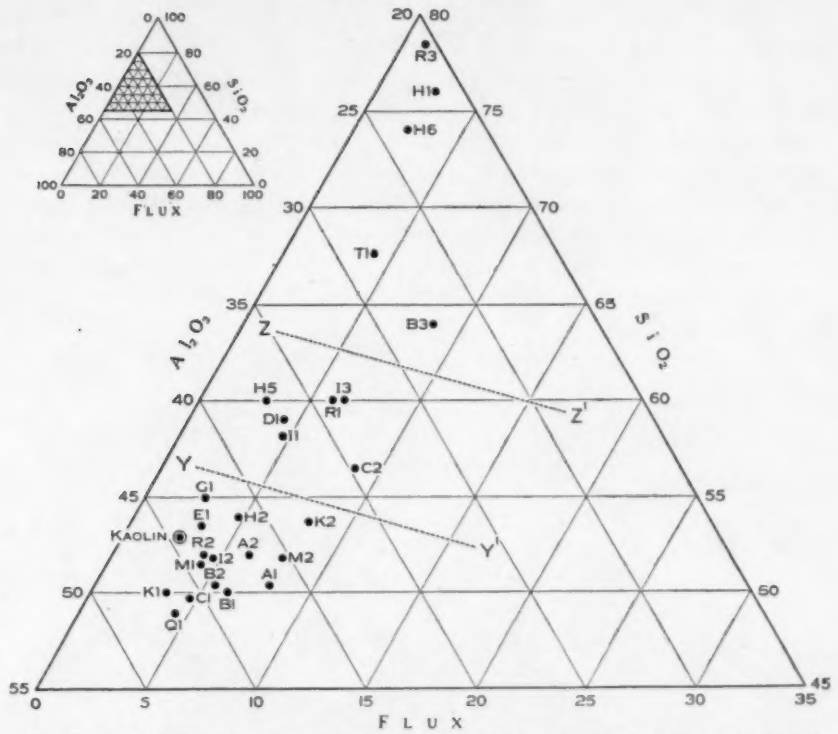

FIG. 12.—A section of a triaxial diagram (the shaded portion enlarged of the small triangle on the left) showing the location of clays according to chemical analyses. A kaolin is included for comparative purposes only.

from which the clays were obtained as well as a brief description of their geologic formation are included. The thermal expansions from 20 to 1000°C of the fire clays fired at 1155°C and 1400°C are given and the clays are grouped according to the several types of expansion. The moduli of elasticity and transverse breaking strengths have been determined after receiving two different heat treatments, and at several different temperatures.

These data show that the thermal expansion of the fire clays determined after firing at 1400°C may be greater or less than that found after firing

them at 1155°C, depending entirely on the composition of the clays. The information given also indicates the successive simultaneous development of cristobalite and mullite, and finally the probable conversion of the cristobalite to a highly siliceous glass.

The moduli of elasticity and rupture of the clays are, with few exceptions, greater after firing at 1400°C than after firing at 1155°C.

Comparing the values for moduli of rupture and elasticity obtained at 550°C with those obtained at atmospheric temperature shows, in general, that the percentage increase in moduli of elasticity and rupture is greater in highly siliceous clays than in aluminous clays. The plastic deflections of the clays, measured at 1000°C are much lower for those fired at 1400°C than those fired at 1155°C and are also lower in the siliceous type of clays than in the aluminous.

The clays are plotted according to chemical composition on a triaxial diagram and are divided into three groups. Those clays which on firing would theoretically contain the greatest percentage of mullite are grouped about a kaolin and have properties which should be very desirable in fireclay products.

THE CASTING OF CLAY WARE—A RÉSUMÉ*

By F. P. Hall

ABSTRACT

Considerable difficulty has been encountered in developing methods suitable for determining the properties of a casting slip that in turn define the casting quality of the slip. A survey of the literature is made, especially that dealing with the colloidal phenomena of clay suspensions, which might be of assistance in solving some of the problems encountered in the use of the casting process.

The term, casting quality of slip, is defined and the factors which influence this property are considered in detail. Control methods proposed by various investigators are discussed critically. A new method of slip control is suggested. The sources and remedies of some troubles encountered in the casting process are discussed.

I. Introduction**

The control of casting slips is a matter of such importance to the ceramic industry that some of the literature on the subject has been reviewed in this paper.

The casting of clay bodies consists of producing bodies of definite shapes from a heterogeneous mixture of clay particles of all sizes and shapes by pouring a thick aqueous suspension of the body components, called the slip, into a plaster of Paris mold. The plaster gradually absorbs a portion of the water from the slip and ultimately the mold contains the green or relatively dry body, which is sufficiently firm or rigid to maintain its shape and to permit handling.

There are two types of casting in use at the present time, namely, the "drain casting" and the "core casting" methods. The first of these consists of pouring the slip into a coreless mold and, after a sufficient thickness of body has formed, pouring out the excess slip; the second is accomplished by pouring the slip into a mold containing a removable core, thus facilitating the formation of ware with heavy sections and obviating the necessity of removing excess slip.

Very little difficulty is experienced in employing the "drain casting" method, even with complex shapes, especially if the ware is thin. Serious difficulties, however, are occasionally encountered in using the "core casting" method for casting heavy products such as sanitary ware, glass pots, large crucibles, retorts, and high-tension electrical insulators, in all of which a uniform structure is required. These difficulties generally result from inadequate control of the physical properties of the slips which, in turn, determine its casting quality.

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** All references will be found on p. 765 at the end of this paper.

It seems to be the consensus of opinion that most of the working properties of clays are largely influenced by the nature and amount of the colloidal material present. Consequently it was thought that a résumé of the literature on the salient features of this subject, especially with reference to the colloidal phenomena affecting clay suspensions, might be of assistance in producing a better understanding of the conditions involved and in overcoming some of the difficulties encountered in the casting of clay bodies.

Before this is done, however, the following general description of colloids and their properties is presented to refresh the reader's mind on the subject and briefly to define or describe some of the pertinent terms or expressions which will be used in the subsequent discussion.

The term "colloid" signifies a state or condition of fineness in which the individual particles are from one-tenth micron (0.0001 mm.) to one millimicron (0.000001 mm.) in diameter. These fine particles when suspended in water may be forced to collect in close compact masses (flocculate) which settle rapidly or to separate into individual particles (deflocculate) which remain in suspension for considerable periods of time. Flocculated and deflocculated particles are sometimes referred to as being in the gel and sol states, respectively. The term "gel" refers to the colloidal material in the coagulated or gelatinized condition and the term "sol" refers to the same material in the dispersed or peptized condition. Since either of these two conditions can be transformed more or less completely into the other by proper treatment, the change is reversible and is often referred to as the gel-sol transformation. This transformation is the result of a change in the nature of the electrical charges on the colloid and may be effected by adding to the suspending medium (dispersoid) flocculators or deflocculators (organic and inorganic compounds) whose electrical charges can neutralize or otherwise affect the charges on the clay particles and cause them to become either coagulated or dispersed (gel or sol state, respectively). If this change proceeds from the sol to the gel state it is called gelation; if from the gel to the sol, solution or peptization.

The expression "p_H" may be defined as that numerical quantity which expresses the degree of acidity or alkalinity of a solution, but does not necessarily involve any consideration of the total amount of acid or alkali present. The p_H of water (which, when pure, is neutral) is 7. As the solution becomes more acid the p_H value decreases below 7. Conversely, as the solution increases in alkalinity the p_H value increases above 7.

The term "lyophile" has been applied to those colloidal systems in which there is a marked affinity between the dispersed phase and the suspending medium and the term "lyophobe" to other somewhat similar systems where this affinity is not so marked. The physical properties of the

lyophile system are very different from those of the pure dispersion medium, while the converse holds for lyophobe systems.

Adsorption is the formation of a continuous film of the dispersoid upon the surface of a solid.

II. Factors Which Influence the Casting Quality of a Slip†

(1) Properties of Clays Used in Composition of Body

One of the most important considerations in the control of slips for casting is the proper selection and proportioning of the clays. It is not sufficient merely to have the correct ratio of clay to nonplastics. Proper clays, of the quick-drying nonwarping varieties, should be selected with great care. The properties of the ball clays used are very important because the slip depends largely upon the ball clay for its fluidity or ability to flow readily into all parts of the mold. The amount of ball clay to be used in a casting slip depends upon the amount and properties of china clay used. The probable limits of the amount of ball clay are from 4 to 20%. Too much ball clay will give a slow setting slip, causing too dense a product or sections of uneven density and the ware is liable to have soft spots. Too much china clay will produce a slip that will not properly fill the mold, decrease the bonding power, produce a porous product, cause a high rate of drying, and the ware is thus liable to crack in the mold.

Experience has indicated the desirability of utilizing a blend of ball clays rather than a single clay because disturbances caused by variations in the quality of the individual clays become correspondingly smaller and by careful blending smoother slip working qualities can undoubtedly be obtained. The mutual effect of one clay upon another was studied by Scripture and Schramm,[1] who stated

> It is therefore apparent that within the range of practical working compositions an increase in ball clays will give increased fluidity to casting slips. The more tender or nonplastic the china clay, the smaller the proportion of ball clay needed to produce a fluid slip. We thus have the apparent paradox that while the highly plastic ball clays confer fluidity to a casting slip, the more plastic of the china clays have the directly opposite effect. We know from the work done on the simple clay slips that the ball clay is deflocculated at a low p_H but has a high absorption factor, while the china clays deflocculate at a higher p_H but have lower absorption factors.

This apparent paradox can be explained by the fact that there is a marked difference in the base-exchange capacity of china clays and ball clays and hence in their sensitivity to electrolytes.

Slightly plastic clays (not including ball clays) are preferable to highly

† In this discussion the term "casting quality" includes (1) casting rate, (2) texture of the cast, and (3) drainage property of the slip. These three conditions must be satisfactory if the casting process is to be used successfully in commercial work.

[1] For this reference and those following, see Section V, References, p. 765.

plastic ones as they require less alkali to maintain suitable fluidity and the ware can be more readily removed from the molds. For this reason finely-ground grog is often used instead of raw clay.

Rohland[2] has stated that the greater the amount of organic colloidal matter in a clay the more susceptible is the clay to the action of alkalis and, therefore, the more suitable it is for casting. This does not appear to apply to organic matter added purposely to a clay.

The use of a coarse-grained china clay along with a ball clay having a high concentration of organic deflocculents seems to give best conditions for casting.

To get a successful casting body it is occasionally necessary to alter the plasticity of some of the clays present. A reduction in the plasticity of the most plastic clays by preheating the clay often enables one to cast this type of clay. Keppeler[3] in discussing this point says

> As is well known, the addition of a definite quantity of alkali greatly increases the "carrying capacity" of the water in this respect. If humic acid is added to the slip the dispersion is further increased. It has been shown that on heating kaolins to 400 °C, the hygroscopicity of the kaolins was reduced from 3.77 to 2.49 and that of clays from 9.34 to 7.12. The practical utility of this method of obtaining casting slips is of the greatest importance when thick-walled ware is to be cast.. Clays that have been preheated usually require in addition to the alkali an acid colloid such as humic acid to make them suitable for casting.

(2) Preparation of Slip The amount of water used in preparing the slip should be as small as possible so that undue shrinkage of the ware may be avoided. In estimating the amount of water to be used in the preparation of the slip, it is necessary to use only dry materials or to take into consideration the amount of free or uncombined water in the raw materials. The amount of water also depends upon the amount of deflocculent used. According to Searle[4]

> If no deflocculent is used, most dry clays will require an almost equal weight of water to convert them into a slip, but with a deflocculent good slips may be produced which contain only about 20 to 25% of water. The proper consistency should be determined, as a slip that is too thick may cause discoloration and staining, even though it produces sound articles, but more often defective pieces are produced. Nonplastic materials may usually be made into dense slips; thus slips for casting zirconia crucibles may weigh as much as 30 oz. per pint.

If water alone is used in the preparation of a slip, a large amount is required, resulting in a large drying shrinkage with probable distortion of the ware. The use of a suitable electrolyte deflocculates clays and renders them more fluid, and the particles will remain indefinitely in suspension. Among the deflocculating agents are water, organic liquids, sodium carbonate, sodium silicate (water glass), the oxides or hydroxides of calcium, barium, sodium, or potassium, and various soluble phosphates, carbonates, and silicates.

M. Simonis[5] has found that lithia is even more powerful than soda in increasing the suspensibility of clays, and that soda is more powerful than potash. The following substances also cause deflocculation although some of them, when at a greater or less concentration than used by the investigators, may have a different effect: sulphates of magnesium, mercury, and sodium; the sulphide, acetate, chloride, and phosphate of sodium and ammonium gallate.

Ashley[6] has stated that the following salts deflocculate clays: sodium oxalate, potassium oxalate, ammonium oxalate, soft soap, borax, potassium phosphate, disodium hydrogen phosphate, sodium dihydrogen phosphate, sodium ammonium hydrogen phosphate, potassium cyanide, potassium ferricyanide, sodium arsenite, potassium permanganate, and many dyes.

In the case of raw clays which contain objectionable amounts of certain impurities it is sometimes necessary to convert the interfering impurities into an insoluble or inert form before deflocculation. As an example, if excessive soluble sulphates are present they should be precipitated by barium hydroxide before adding the deflocculating agent.

It is most important in adding a deflocculating agent that exactly the right proportion should be added, as too much or too little may cause a reverse action. According to Searle[4]

> Sodium carbonate used alone produces a high surface tension and the solid particles tend to "ball up" and cause the entanglement of air bubbles. The use of sodium silicate alone tends to produce a stringy slip and does not hold the clay in suspension as well as sodium carbonate.

The order of addition of materials to the slip seems to affect the initial casting quality of the slip. Schory[7] discusses this subject as follows:

> The properties of a casting slip which it is desirable to maintain constant are the specific gravity, the viscosity, the rate of casting, the firmness of the cast, the cleanness of drainage of surplus slip from the cast, the hardening and drying of the cast in the mold, and low shrinkage of the cast during the early stages of hardening and drying. Viscosity and specific gravity do not furnish much information concerning the action to be expected of the slip in the mold. A slip may be prepared having any desired water content and viscosity and still be an utter failure when used in the casting shop. A body was prepared by twelve methods using in each case the same proportions of body, water, sodium carbonate, and sodium silicate, and each method gave a slip of different viscosity even though the specific gravity and alkali concentration were constant. The method that gave the lowest viscosity was as follows: To the water in the blunger was added the sodium carbonate. The filter press cakes were charged into the blunger and the sodium silicate was added last. Of the slips prepared by blunging, those with the lowest content of alkaline reagents gave the firmest casts. The methods of preparation requiring greater amounts of sodium salts to bring the slips to their best casting condition gave slips which did not cast so firm.

From the time that the alkali is added to the slip until the ware is removed from the mold, the slip should be kept warm (90°F or slightly

higher). This facilitates the removal of the water from the slip by the mold and retards the gelatinization of the slip. Variations in temperature may cause changes in the viscosity of the slip and this change is not regular. In many cases high viscosities in the same slip may be obtained at a low and a high temperature, while between the low and high temperatures the viscosity will be materially less than the maximum. Weber[8] has utilized this property in the making of glass-melting pots by carefully determining the temperature and amount of electrolytes required to produce a slip of maximum fluidity and concentration. The necessary increase in temperature is usually so slight that it can generally be produced by a vigorous stirring of the slip in a mechanical agitator. A few minutes after the slip has been put into the mold the small amount of water absorbed is sufficient to effect the gelation of the remaining colloid and further storage produces an effective casting of any desired thickness.

(3) Colloidal Material Present The amount and condition of the colloidal matter in the slip control to a considerable degree the movement of water through the slip during the "setting up" of the cast. The condition of the colloidal matter is determined by the presence of certain substances such as flocculators and deflocculators. The kind and amount of these agents present determine the proportion of the total colloidal material in the sol and gel state.

In the casting process the agents controlling the sol-gel transformation are derived from (1) the clays, (2) blunging water, (3) the "dope" used, such as water glass, soda ash, etc., and (4) the plaster mold.

The amount of colloidal material present in the slip is controlled by the kinds and amounts of clays used in compounding the body. A method of estimating the amount of colloidal material present in soils has been described by the U. S. Bureau of Soils[9] and can be recommended to the ceramist for estimating the colloidal content of clay.

The data accumulated by these investigators indicate that, as a rule, less than 5% of the adsorptive capacity of a soil should be attributed to the unaltered mineral particles and that 95% or more is due to the colloidal material. The almost complete localization of the adsorption in the colloidal matter probably is due primarily to the colloidal material being of quite a different nature from the soil particles. While the noncolloidal part of the soil is made up of unaltered soil minerals, the colloidal material is doubtless made up chiefly of inorganic gels together with amorphous organic matter. They conclude that "adsorption by noncolloidal constituents should, therefore, not seriously affect adsorptive methods for determining the amount of colloids in soils."

The earliest method of determining the amount of colloidal material in soils consisted in actually separating the material from the rest of the

soil. The chief source of error in this method is the difficulty of obtaining a complete peptization of the colloidal material and the error may be enormous in some cases. The adsorption method of determining the colloidal content of soils involves determinations of the adsorptive capacities of the soil and of the colloidal material extracted from these soils by the use of the supercentrifuge. The ratio of the two adsorptive capacities multiplied by 100 is regarded as the percentage of colloidal material present.

The water-vapor adsorptive capacity of the colloidal material is determined by deflocculating a clay that is to be investigated; passing the suspension through a supercentrifuge at such a speed that the particles with diameters greater than one micron are thrown out of suspension; filtering the remaining suspension by means of ultra-filters; and determining the change in weight when the separated colloidal material is placed in a chamber at constant temperature and humidity and allowed to remain there until constant weight is attained. After this it is dried at 110°C for 18 hours. In this work the material is placed in a humidifier at a temperature of 30°C. A $3^1/_2\%$ solution of sulphuric acid is usually used in the humidifier. Information, however, regarding the type of colloids present has been obtained by determining the adsorptive capacities of the colloidal material over both $3^1/_2\%$ and 30% sulphuric acid solutions. The adsorptive capacity of the original clay is then determined by weighing out a small amount of the clay and placing it in the humidifier along with the colloidal material. The amount of colloids is estimated by means of the equation:

$$\% \text{ colloids} = \frac{Y}{D} \times 100$$

Where Y = amount of water vapor adsorbed per gram of clay under specific conditions
D = amount of water vapor adsorbed per gram of colloid (separated from the same clay) under the same conditions.

Information regarding the amount of colloidal material present in the various clays should be useful when one clay is to be substituted for another and in selecting a clay that might be suitable for casting.

The condition of the colloidal material in the slip is probably one of the most important factors in determining its casting quality. The term "condition of colloidal material" in this discussion is used to denote the existence of the material either wholly in the sol or gel state or partly in the gel and partly in the sol state. A certain amount of the colloid must be in the sol state to permit casting with the minimum amount of water. If too much is in this state, however, the inert material, such as flint and feldspar, will settle and produce a nonuniform body. The sol-gel transformation has been the subject of many investigations and the exact mechanism of this process is still more or less an open question.

As far as clay colloids are concerned the process is reversible provided the material is not altered by heat.

Information concerning the factors affecting the condition of colloidal material in clay slips can best be obtained by a study of the literature pertaining to suspensions.

Concerning the stability of suspensions, Burton[10] states that

> the existence of the colloidal particle is fundamentally due to an equilibrium maintained between the forces of surface tension and the repulsion due to the electrical charges. The dominating factor in bringing about coagulation in the dispersoids is undoubtedly the neutralization of the charge possessed by the particle. This may conceivably be done by so altering the properties of the liquid medium itself that dissociation producing the electric double layer is lessened; this would bring about at least a partial recombination of the two charged layers. However, in most cases the experimental results point to an adsorption by the particle of ions bearing a charge opposite to that of the particle.

The work of Hardy[11] and that of most of the investigators since that time has shown that the electrical charge of the particles plays an important rôle in flocculation and deflocculation.

It is well known that clays differ widely in their response to the action of flocculators and deflocculators. The base exchange capacity of a clay very probably determines the sensitivity of that clay to the action of flocculators and deflocculators and the concentration range over which the clay is flocculated, as some clays are known to have a very short casting range, that is, a very short concentration range over which they can be successfully cast.

Regarding the exchangeable bases Hissink[12] states:

> The exchangeable bases are located on the surface of the soil particles; in other words they occur in the adsorbed condition. The cause of this adsorption is to be sought in the chemical attraction between the bases and the soil acids (clay and humic acids). When the soil is treated with water, a soil suspension is formed. Part of the surface molecules then become ionized, forming around the surface of the adsorbing clay and humus particles an electrical double layer. In the inner part of this double layer (so-called Helmholtz layer) are found the anions of soil acids, in the outer part the cations; H^+, Mg^{++}, Ca^{++}, K^+, Na^+.

Methods of determining the base exchange capacity of soils and clays are described by M. S. Anderson and Sante Mattson,[13] and by Sante Mattson.[14]

The presence of certain organic sols is known to affect the sensitivity of a clay to the action of inorganic flocculators and deflocculators. When an organic sol is mixed with an inorganic sol of the same charge we often get a so-called "protective action," that is, the organic sol protects the particles of the inorganic sol from coagulation by electrolytes. Certain electrolytes, such as sulphates, seem to accelerate the velocity of setting of the gel. There is probably no sharp distinction between the formation of a gel and a flocculent precipitate. Electrolytes play a very important part in the swelling of gels. Among the interesting properties of colloidal

substances is the tendency of certain sols to precipitate when mixed and the apparent indifference of other sols to each other. This mutual precipitation may be due either (1) to neutralization of electric charges, or (2) to chemical action between the peptizing agents. The amount of organic matter in the ball clays seems to have a marked effect on the amount of alkali required to deflocculate the clay. The organic deflocculents seem to act very much more slowly on the clays than the inorganic deflocculents. It is advantageous to have a certain amount of organic material present in order to minimize the gelation of the slip during the time that the slip is in the storage cellar and in the mold.

(4) Action of Electrolytes on Clay The action of electrolytes on clay slips has been studied by a great number of investigators and the results of some of their studies are summarized as follows:

(1) Neubert[14] gives the following explanation of the liquefaction of clays by alkali:

On the addition of an alkaline solution of suitable concentration to clay, the clay particles adsorb the hydroxyl ions and repel each other. The mass becomes fluid as a result of the increased mobility of the clay particles. After a time, stiffening, occasioned by the swelling of the clay particles, sets in. The humus substances contained in the clay also swell, and are thereby empowered to form alkali humate, but only a small amount of alkali can be removed from the adsorption equilibrium in this way, since the alkali humate formed is extensively hydrolyzed, and again furnishes hydroxyl ions. As the alkali addition increases, its suspending effect becomes so marked that the stiffening resulting from swelling becomes continually less perceptible. Liquefaction is also facilitated by the splitting up of the clay particles which results from the solution of humus by the alkali. At the point of maximum liquefaction the two effects, swelling of the clay particles and splitting up of the clay particles determine the equilibrium, but the splitting effect is not yet marked; it first appears prominently in the reliquefaction. If the alkali concentration is now raised above the optimum, coagulation of the individual particles occurs, and the slip stiffens. If a sufficiently high concentration of alkali is now used, the hydroxyl ions force the alkali humate, which has a protective effect, from the adsorbing surface. This should again lead to the stiffening of the slip. But the high concentration of alkali provides the possibility of an increasingly extensive splitting of the clay particles. New adsorbing surfaces come into play, and the amount of alkali humate is increased. The clay is again gradually converted into the fluid condition. It is reliquefied. With further increases in alkali concentration, the reliquefaction gradually becomes less, since (1) the increase in the amount of alkali humate is limited by the humus content of the clay, (2) less alkali humate remains adsorbed with increasing hydroxyl ion concentration, and (3) the decrease in amount of alkali humate at higher hydroxyl ion concentrations as the result of the appearance of fresh surfaces will not necessitate a corresponding decrease in the amount of adsorbed hydroxyl ions. The clay slip will then remain stiff.

(2) Bleininger[16] discusses the effect of flocculators and deflocculators and the effect of time on gelatinization as follows:

Organic colloids appear to act somewhat similarly to the sodium salts in bringing about increased dispersion; but at the same time the latter seem to protect the particles

against flocculating actions, so that suspension is less sensitive to the action of coagulating salts. The alkaline, fluid, casting slip without the presence of sufficient amounts of organic colloids is at once changed to the stiffened condition by the introduction of salts like the sulphates or chlorides of calcium, magnesium, or aluminum. Therefore, the presence of such salts in the clays not only requires an increased amount of alkali to bring about deflocculation but also may even render the maximum liquefaction impossible. . . . .

It seemed evident from the results obtained that slips containing just sufficient or less than sufficient alkali to bring about maximum deflocculation were more apt to show fluctuation in viscosity (with time) than those containing more than the required amount. The time factor is explained, first, by the fact that the action of the alkalis upon the dispersed matter is often quite slow unless vigorous agitation is kept up constantly; second, the concentration of alkali may change also because of adsorption and reaction with silica or the soluble sulphates. It is necessary therefore in preparing slips to know the time effect. Sodium silicate is a more effective reagent as far as the reduction of viscosity is concerned than sodium carbonate.

(3) In regard to the use of water-glass solution for deflocculating agents in clay slips Kieffer[14] states

Colloidal SiO_2 acts as a protective colloid. It is necessary to have water-glass with a high SiO_2 content to prepare slips which cast easily with kaolins, while for clays having a high humus content, perhaps a water glass having a high Na_2O content is best.

(4) McDowell[18] found that those sodium silicates high in silica were the most potent in their effect on the rate of flow of slips through a viscosimeter for a given amount of Na_2O. The effects with the sodium silicates were also more pronounced than those obtained with NaOH, Na_2CO_3, or silica sol which were used for comparisons.

(5) The use of an alkali humate as a deflocculating agent is suggested by Neuss.[19] The effect of salts in the blunging water often causes trouble in the casting shop. The sulphates of calcium and magnesium are very harmful in this respect as they tend to counteract the effect of the deflocculators added. Mellor[20] considers this point as follows:

When sodium silicate was used in casting slips it was noted that the slips gelatinized or became slimy, usually on the surface. Works in some districts were troubled with this more than plants in other districts. This may be due to the action of CO_2 in the air on the slip which tends to coagulate it. Lime in the water in the form of acid carbonate may also coagulate the slip. It was found that water, purified by the "permutite" process, permitted one to prepare a slip with a lower per cent of soda than was the case when the impure water was used.

(5) Type and Condition of Plaster Mold Used

Plaster molds have a limited capacity for taking up water and for draining water through a deposit of clay. If the power of the mold could be increased so as to take up more water and permit of draining from a great thickness of clay, the application of the casting process would be less limited. The application of a vacuum chamber to the outside of a plaster mold is suggested by Allen[21] as a means of increas-

ing the thickness of casting. This process was used at Sèvres about sixty years ago and was developed by M. Victor Regnault. Weber[8] discusses the use of plaster molds as follows:

> Gypsum is the most suitable material for casting molds, as it not only absorbs a considerable quantity of water from the casting slip and causes a quicker stiffening, but also by its chemical action upon the casting slip coming in contact with the water of the slip a minimum quantity of calcium sulphate dissolves, which acts directly by gelatinizing the colloid substances and helps to quicken the formation of a firm skin of clay on the walls of the mold.

The density of the plaster mold controls to a certain extent the rate of casting and the quality of the ware. A dense mold often produces pits or pinholes in the cast ware caused by the air which is forced out of the mold. In many cases it is necessary to first coat the mold with slip before casting in order to get rid of bubbles in the cast ware. Bubbles are due to wet molds, dense molds, incorrect water content of the slip, and to improper method of casting. Hind[22] seems to have recognized the importance of the condition of the plaster mold as affecting the casting of clay ware, for among the following factors considered by him as having the greatest influence on slip casting are several referring to the mold:

(*a*) Time required for casting slip in a plaster mold to give the required thickness of solid casting.
(*b*) Alteration, if any, of the slip during casting. For example, it is conceivable that the slip poured off from the mold has less proportion of water than that originally used.
(*c*) The proportion of water in the original slip.
(*d*) The proportion of water in the cast clay on the mold.
(*e*) The porosity of the mold.
(*f*) The degree of saturation of the mold.
(*g*) The temperature at which casting takes place.
(*h*) The viscosity and thickness of the casting slips.
(*i*) The resistance of the cast clay to the passage of water.

The molds should be kept reasonably warm to hasten the movement of water from the side that is in contact with the ware to the outside of the mold where it evaporates. A reasonable amount of dry, warm air should be circulated about the molds to hasten this evaporation.

(6) Additional Factors One of the common troubles with cast ware is unevenness or warping of surfaces. The trouble may often be traced to grinding the body too fine or to adding too much soda to the slip. The variation in the density of the plaster mold is also a source of this trouble. Worthington[23] found that the amount of contraction to which cast ware is subject in the biscuit oven is dependent upon the weight of solids per pint of slip. Ware cast with a light slip shows least contraction but is more liable to show crazing than ware cast with a heavy slip. Some clays containing soluble sulphates do not respond readily to the addition of alkalis and the reduction in viscosity can be obtained only by adding water. In some of the German plants using the

casting process, the soluble salt content of the clays is determined on each shipment. The presence of these salts is due either to the fact that they are associated with the clays as they are mined or that they are added in the purification process.

McDougal[24] states

A body slip that has too low a content of salts behaves in the mold much the same as the original slip, giving a soft cast, one hard to drain cleanly and difficult to dry safely. A solid cast made from this slip shows a soft center. Slips with the proper content of salts give a cast that feels solid and drains cleanly. A slip containing too great a concentration of salts casts rather quickly at first and sticks in a hard layer to the walls of the mold. When a layer about one-quarter inch thick has been formed, the slip will stop casting and deposit no more clay. It is also difficult to keep such a slip in suspension as settling takes place. It is in the use of scrap from the casting shop that the greatest danger of wide variation arises. The sodium silicate, having been "set" by the heat of drying, is no longer noticeably soluble and it therefore has no effect as a soluble salt. The clay gel that has not been converted into sol by the salt solution is "set" by the drying-room temperature.

III. Methods of Plant Control of Casting

The difficulties which were encountered in the application of the casting process to plant scale in 1915 were about the same as those at present. They are summarized by McDougal[24] as follows:

(1) Where no soluble salts are employed, variations arise from the use of slips varying in clay content and in proportion of dry scrap clay used.

(2) Improper preparation of the slip to be cast, often a result of erroneous adoption of recipes governing the use of sodium carbonate and sodium silicate.

(3) Insufficient regard for the relatively narrow limits within which the properties of the slip used may be allowed to vary.

(4) Poor selection of china and ball clays from which the clay content of the compounded bodies is derived.

(5) Improper condition of the mold.

In the casting of light ware the control of the so-called "viscosity" and the specific gravity of the slip seems to be sufficient for all practical purposes. With heavy ware, however, these tests seem to be insufficient and a great many attempts have been made to devise methods for measuring the properties of a slip that directly or indirectly determine its casting quality. Hall[25] suggested the Bingham plastometer for determining the consistency of slips and the relative plasticities of clays. Fritz and Donnenwirth[26] have used this apparatus and report their conclusions as follows:

The Bingham plastometer, like the settling test, will usually classify clays as to their casting value. We find that, as a rule, clays which show low plasticity according to this test are the best as casting clays. Plasticity tests do not, however, indicate the sometimes serious variations in a clay which alter its casting behavior. . . . For thick castings the ball clay should be kept as low as possible. . . . We have fast-casting clays and slow-casting clays among both the china clays and ball clays. . . . The

amount of electrolyte varies from day to day and this variation is probably due to a variation in the soluble salts of the clays used. . . . For the casting process we have not been able to get an American china clay that will cast the very thick sections that we have to cast. . . . We have no difficulty with American ball clays.

Considering the effect of the viscosity of the slip on its casting qualities Sanborn[27] states

Slips of high viscosity cast very rapidly and the time of casting increases as the viscosity decreases. . . . When solid pieces are cast with slip of very high viscosity the portion of the slip in contact with the mold will cast very fast. This part will shrink away from the mold, leaving an excess of water in the center. This results in a piece of varying density which will often crack in the drier due to the increased amount of water which must be removed. . . . It is possible to obtain the same viscosity at two points on the viscosity-electrolyte curve as it has a minimum. The portion of the curve at the left (low salt concentration) is the one used in general practice. Slow casting and drying are encountered when slip corresponding to the portion of the curve at the right (high salt concentration) is used. . . . Difficult control of the slip and blistering are eliminated by the use of organic electrolyte.

The determination of the p_H value and the electrical conductivity of the slip have both been suggested as means of slip control. These two methods are both indirect and could only be used successfully providing the following factors were determined and held constant: (1) the amount of water in the slip, (2) type of electrolyte, (3) soluble salt content of clays and amount of salts in blunger water, (4) in case water glass is used, the ratio of Na_2O/SiO_2, and (5) composition of body.

According to Searle[28]

Many of the experiments made on the effect of various substances on the viscosity and other properties of casting slips appear to have been made without sufficient recognition of the many factors involved. To understand what may be taking place, it is necessary to bear in mind the effects of

(1) The quantitative relationships of the water-content of the system to the remaining material;

(2) The chemical conversion of "neutral" compounds into basic or acidic derivatives;

(3) The alterations in solubility and hydration capacity accompanying the reaction;

(4) The types of system produced (whether all hydrated colloid, all solution in water, a mixture of colloid and noncolloid, or subdivisions of any of these); and

(5) The changes in viscosity incident to the "emulsification" or "suspension" of any of the unchanged "clay" in such derivatives as may be produced. How inadequate for the understanding of the colloid-chemical behavior of such systems are the usual ideas of "stoichiometry," "chemical affinity," "electrical charges," "hydrogen and hydroxyl ions," which are usually regarded as exclusively explaining them, is self-evident.

A general casting formula is derived and tested experimentally by Hind[22] who says

For a normal casting slip the thickness of the casting is given by

$$L^2 = 200\, X \sigma d\, (1 - S^2)$$

Where L = thickness cast in mm., in time, t, hours
X_0 = the rate of passage of water through 1 cm. cube casting onto a dry mold in cc. per hour
r_0 = ratio of volume of casting to volume of water removed
S = ratio of water in mold to water required to saturate the mold.

It is concluded from the data presented that the general casting formula may be taken as reasonably exact when the mold is not more than half saturated.

It is evident that the condition of the slip, or what might be called the "castability" influences the value of L through its effect on X_0. Work along this line is fundamental and should be continued.

A more direct method of plant control of casting slips such as the use of the Bingham plastometer or modified form of this apparatus seems to be the most promising method. An apparatus which the writer would like to suggest consists of a perforated funnel, such as the Beuchner funnel, with the perforated surface covered by a thin sheet of plaster of the same density that is being used in the molds. The funnel is placed over a suction flask and the slip to be tested is poured into the funnel and suction applied. The amount of water drawn through the funnel is determined from time to time as this is proportional to the thickness of the clay layer formed on the plaster. The thickness of the plaster plate used will be determined by the body of the slip in use at the plant at that time. In some cases it might be desirable to apply a constant pressure to the top of the funnel instead of a suction to the flask. The time-flow curve under a constant pressure head obtained from such an experiment should serve as a direct method of slip control.

IV. Recapitulation

(1) The casting range of each clay should be investigated and those selected which have the widest casting range. At the same time it is well to investigate the mutual effect of one clay upon another in order to get a mixture of clays having the widest casting range and the best casting qualities. The use of coarse-grained china clays along with ball clays having a high concentration of organic matter seems to give the best results.

(2) It is very important that the slip be kept luke-warm during the storage period and during the time that it is in the mold.

(3) The action of electrolytes on slips is best explained by the variation of electrical charges on the individual particles which is caused by the adsorption of one type of ion from solution and the presence of other ions in the suspending medium.

(4) Clay colloids have been characterized as being neither typically lyophilic nor typically lyophobic, but possess some of the properties of both classes.

(5) The presence of certain flocculating ions as Mg^{++}, Ca^{++}, and SO_4^{--} derived from the blunger water, the clays, and the scrap that has been contaminated with plaster, is thought to be a source of a considerable number of the variations experienced in the daily control of the casting quality of slips in the plants. The use of soft water, clays with a minimum of soluble

salts, and the careful control of the scrap are suggested as methods of minimizing these variations. Press water should not be used continually as it becomes saturated with harmful salts.

(6) Gelation of slips is a source of considerable trouble and is probably caused by the progressive hydration of the individual clay particles. In order to minimize this effect it is best not to allow the clays, particularly the ball clays, to become very dry previous to use, but to store them in a damp cold place for some time before using them. The use of organic deflocculators which seem to be slower than inorganic deflocculators in their action is also suggested as a means of minimizing the "livering" of slips which have stood for some time.

(7) It is better to use some direct method of slip control rather than such indirect methods as p_H and conductivity determinations. The amount and character of soluble salts present in the slip before the addition of the "dope" should serve as valuable information in the slip control.

(8) The development of organic deflocculents appears to offer the most promising solution of the problem of casting heavy ware. The use of peat muck or tannic acid has been suggested. The use of these deflocculents along with a certain amount of water glass and sodium carbonate will decrease the amount of inorganic deflocculents required and reduce the tendency to form scum on the fired ware which interferes with the glazing of that ware.

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THE PACKING OF PARTICLES[1]

By A. E. R. Westman[2] and H. R. Hughill[3]

ABSTRACT

It is axiomatic that the mode of packing of very large volumes of particles of uniform shape and size is independent of the size of the particles, provided they are large enough for the effect of electrostatic forces, air films, etc., to be negligible. An apparatus is described, in which equal true volumes of approximately spherical particles, ranging in diameter from 0.2 to 0.0035 inch, pack practically to the same apparent volume. This apparatus was used in studying the packing of mixtures of two and three sizes of particles. By plotting the data so obtained in diagrams of a particularly convenient character, it is shown that the apparent volumes of mixtures containing unit real volume of solid fall between limiting values which can be calculated from simple assumptions, and that their deviation from these limits depends in a definite manner upon the diameter ratios of the component particles. The conditions governing the application of the results of the study to ceramic technology are pointed out.

I. Introduction

(1) Importance of Particle Packing A very large proportion of the natural and manufactured materials with which we have to deal are aggregates, or contain aggregates, of particles of several sizes or shapes. An understanding of the packing of particles is of great importance, therefore, in almost every branch of science and industry. The ceramic industry is not an exception to this general statement because practically all ceramic materials, with the probable exception of glasses and glazes, consist of aggregates of natural or artificial minerals. It is well known that a number of important physical properties of refractories, grinding wheels, terra cotta, etc., depend to a considerable extent on the closeness of packing of the aggregate.

(2) Scope of Study A study of the packing of particles was initiated in the fall of 1923 in the Department of Electrochemistry of the University of Toronto. During the first year the study was limited to the packing of approximately spherical particles of sizes greater than 200-mesh (0.0029 in.) and to mixtures containing not more than three sizes of particles. This first year's work forms the basis for the present paper. The information obtained in later work, in which the effect of particle shape, air film, etc., was investigated, will be presented in a future paper.

II. Apparatus

(3) Requirements The closeness of packing of very large volumes of particles of uniform shape and size is independent of the size of the particles, provided electrostatic and air-film effects are

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negligible. In studies of particle packing, therefore, it is a decided advantage if the apparatus is such that the packing of uniform particles is independent of their size. In studies of mixtures of particles of different sizes, it is also important to have an apparatus in which segregation can be avoided. The first part of the study was devoted, therefore, to the development of an apparatus and method of packing which met the foregoing requirements.

(4) Description A diagram of the apparatus which was developed is shown in Fig. 1. It consisted essentially of a cylinder, a piston, and a cam and pin. The cylinder was made from a seamless brass tube, 14 inches high, $2^{1}/_{16}$ inches internal diameter, and $2^{3}/_{8}$ inches external diameter. This was set on a copper base, $3^{3}/_{8}$ inches in diameter and $^{1}/_{2}$ inch thick. The piston consisted of a brass tube, 8 inches high and $2^{1}/_{32}$ inches external diameter, closed at the lower end. The piston was graduated in such a way that the volume of a mixture of particles in the cylinder could be determined by placing the piston on top of the mixture and reading at the top of the cylinder. The cam and pin arrangement was such that at each revolution of the cam, the cylinder was slowly elevated and then suffered an unimpeded drop of about 3 inches on to a felt pad shown in the diagram. The cam was driven by an electric motor at such a speed that the cylinder was bumped approximately 25 times a minute.

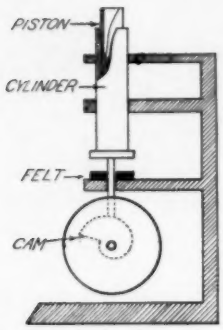

FIG. 1.—Apparatus for packing particles.

(5) Operation In packing a mixture of particles, bumping was continued until a minimum volume was obtained. This required from 30 minutes to three hours, depending on the mixture. When packing mixtures of very fine and very coarse particles, segregation of the fine particles in the bottom of the cylinder sometimes occurred. To overcome this difficulty, the coarse particles were put in the cylinder first and the fine particles placed on top. On bumping such a combination, the volume decreased to the minimum value as the fine and coarse particles mixed and then increased again as segregation took place. No segregation was evident at the minimum volume which was taken to be the packed volume of the mixture.

III. Particles of Uniform Size and Shape

(6) Materials In experiments with aggregates composed of particles of uniform size and shape, lead shot, steel ball bearings, round California beans, poppy seeds, and round washed sand were used. The lead shot and steel ball bearings were spherical; the beans, poppy

seeds, and sand were approximately spherical. The fine sand was more angular than the coarse sand, due to the tendency of angular particles to concentrate in fine portions when screening. The materials chosen covered a wide range of specific gravity. The specific gravity of the lead shot was 11.25; of the fine sand, 2.75; of the medium sand, 2.76; and of the coarse sand, 2.69.

(7) Data The data obtained from experiments with particles of uniform size are reported in Table I. The true volume of each cylinder of particles which was packed in the apparatus was calculated from the weight of the particles and their specific gravity. The "per cent void" and Va, the apparent volume occupied by unit true volume of the particles, were calculated from the true volume and the minimum apparent volume on packing.

TABLE I

DATA OBTAINED BY PACKING PARTICLES OF UNIFORM SIZE AND SHAPE

Material	Diameter (in.)	% Void*	Va†
Lead shot	0.19	36.9	1.58
"	0.15	36.9	1.58
"	0.11	37.0	1.59
"	0.07	36.9	1.58
Steel ball bearings	0.312	39.2	1.64
Round Calif. beans	0.27 (approx.)	37.5	1.59
Poppy seeds	0.04 "	39.8	1.66
Round washed sand: 4–6 mesh	0.176	37.7	1.61
20–28 "	0.028	38.2	1.62
48–65 "	0.0097	38.6	1.63
150–200 "	0.0035	42.5	1.74

* Percentage of apparent volume not occupied by solid particles.
† The apparent volume containing unit true volume of solid particles.

(8) Conclusions The data in Table I show that particles of uniform shape and size could be packed practically to the same extent over a range of diameters extending from 0.312 to 0.0035 inch. In addition, the closeness of packing was not affected by the specific gravity of the material used. The apparatus, therefore, met the requirements given in paragraph 3.

The data also show that spherical particles tend to pack to a per cent void of about 40. It is interesting to compare this value with that calculated for spheres piled in regular arrangements.

When spheres are piled in a regular cubic arrangement, in which each sphere touches six other spheres, the per cent void is 48 and Va is 1.910; when spheres are piled in close hexagonal formation, in which there are twelve contacts per sphere, the per cent void is 26 and the Va is 1.350. The observed values for per cent void fall between these two values, so the packing was neither cubic nor close hexagonal. When spheres are piled so that the packing in any horizontal layer is hexagonal but in any vertical section is cubic, the calculated per cent void is 39.5 and Va is 1.653. These do not differ greatly from the observed values, and it was

noticed, particularly with the large spheres, that a vertically cubic and horizontally hexagonal packing was the prevailing tendency. The packing which was secured in the apparatus may be regarded, therefore, as a mixture of cubic and hexagonal packing which approached a regular arrangement, hexagonal in the horizontal direction and cubic vertically.

IV. Mixtures of Particles of Two Sizes

(9) Materials Three grades of round, washed sand, which will be differentiated as "coarse," "medium," and "fine," were obtained by sieving through Tyler sieves. The coarse sand passed through a sieve with a 0.185-inch opening and was caught on one with an opening of 0.168 inch; the medium sand passed through a 0.0328-inch opening and rested on a sieve with a 0.0232-inch opening; the fine sand passed through 0.0041-inch openings and was caught on 0.0029-inch openings. The diameters 0.176, 0.028, and 0.0035 inch were assigned to the coarse, medium, and fine sand, respectively. These diameters were in the proportion 50.5:8:1. The values of Va for the three two-size systems, coarse-fine, coarse-medium, and medium-fine, were determined by the apparatus and procedure described in Chapter II. The mixtures were made up on the basis of real volumes, the densities of the coarse, medium, and fine sand being 2.69, 2.76, and 2.75.

(10) Data The data obtained by experiments with mixtures of two sizes of sand are given in Table II. These data are presented in two forms, the more usual form in which the per cent void and the per cent composition by true volume of each mix is reported; and a more convenient form for calculation and plotting, in which the volume of Va is reported instead of per cent void and the composition of the mixes is given in terms of x, y, and z, x being the true volume of coarse, y the true volume of medium, and z the true volume of fine, in unit true volume of mix. The value of Va which corresponds to a certain per cent void can be calculated readily by means of the equation

$$Va = \frac{100}{(100 - \text{per cent void})} \qquad (1)$$

TABLE II

(A) COARSE–FINE SYSTEM

Coarse (% by true volume)	Fine (% by true volume)	Void (% by volume)	x	z	Va*
100	0	37.7	1.0	0.0	1.605
90	10	31.5	0.9	0.1	1.460
80	20	25.1	0.8	0.2	1.335
70	30	18.5	0.7	0.3	1.227
60	40	23.6	0.6	0.4	1.309
50	50	27.9	0.5	0.5	1.387
40	60	31.6	0.4	0.6	1.462
20	80	37.8	0.2	0.8	1.608
0	100	42.5	0.0	1.0	1.739

(B) COARSE–MEDIUM SYSTEM

Coarse (% by true volume)	Medium (% by true volume)	Void (% by volume)	x	y	Va*
100	0	37.7	1.0	0.0	1.605
90	10	32.0	0.9	0.1	1.471
80	20	27.8	0.8	0.2	1.385
70	30	26.2	0.7	0.3	1.355
60	40	27.0	0.6	0.4	1.370
50	50	28.2	0.5	0.5	1.393
40	60	30.2	0.4	0.6	1.433
20	80	34.8	0.2	0.8	1.534
0	100	38.2	0.0	1.0	1.618

(C) MEDIUM–FINE SYSTEM

Medium (% by true volume)	Fine (% by true volume)	Void (% by volume)	y	z	Va*
100	0	38.2	1.0	0.0	1.618
90	10	32.8	0.9	0.1	1.488
80	20	29.0	0.8	0.2	1.408
70	30	26.7	0.7	0.3	1.364
60	40	27.6	0.6	0.4	1.381
50	50	30.2	0.5	0.5	1.433
40	60	33.0	0.4	0.6	1.493
30	70	35.6	0.3	0.7	1.553
20	80	38.6	0.2	0.8	1.629
10	90	40.4	0.1	0.9	1.678
0	100	42.5	0.0	1.0	1.739

* The apparent volume occupied by unit true volume of mix when packed in the apparatus shown in Fig. 1.

The values of Va given in Table II are plotted in Figs. 2, 3, and 4. In each of these figures, the composition scale at the base shows the composition in terms of true volumes, the total true volume being unity.

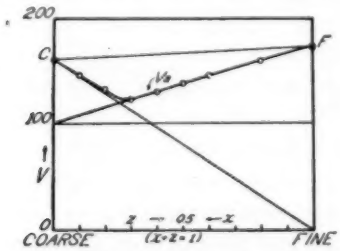

FIG. 2.—Packing in two size systems: Diameter ratio = 50.5.

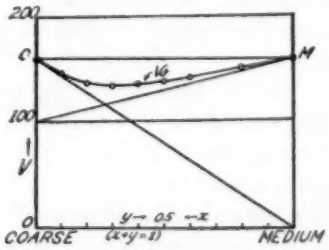

FIG 3.—Packing in two size systems: Diameter ratio = 6.3.

The perpendicular scale is a scale of volume, V. Experimentally determined values of Va are shown by small circles through which a smooth curve has been drawn. The horizontal line at $V = 1.00$ gives the true volume of the mixture, and the vertical distances from this line to the Va curve give the volumes of air in the different mixes for unit true volume of solid. The straight lines joining the values of Va for the end members

of the series, *e.g.*, the line, *CF*, in Fig. 2, gives the apparent volume of the constituents before mixing; the perpendicular distances from this line to the *Va* curve show the shrinkage on mixing.

It will be observed that the *Va* curves in Figs. 2, 3, and 4 are festoons. When the ratio between the diameter of the large and small particles is large, *e.g.*, Fig. 2, the festoon has a very decided droop; when the diameter ratio is small, *e.g.*, Figs. 3 and 4, this droop is much less.

(11) Limiting Cases The relation between the diameter ratios of two sizes of sand and the shape of their *Va* curve can be shown by considering certain limiting cases. Using Fig. 2 for illustration, it is evident that if the diameter ratio is unity, *i.e.*, the coarse and fine particles have the same diameter, there will be no shrinkage on mixing and the *Va* curve will be the straight line, *CF*. On the other hand, if the coarse particles have a diameter which is infinitely greater than that of the fine particles, a different *Va* curve will be obtained. On adding fine particles to a quantity of coarse particles, the fine will pack in the voids in the coarse and the apparent volume of the mix will be equal to that of the coarse particles. The *Va* curve corresponding to this state of affairs is a straight line joining the point *C* in Fig. 2 with the right hand lower corner of the diagram. On adding coarse particles to a large quantity of fines, the solid coarse particles will be immersed in the fines and the *Va* curve will be the straight line joining *F*, Fig. 2, to the point 1.00 at the left side of the diagram. These straight lines cross at *R* and thus *CRF* gives the *Va* curve for the case when the coarse particles are infinitely larger than the fine particles.

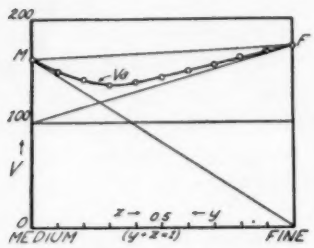

FIG. 4.—Packing in two-size systems: Diameter ratio = 8.0.

The experimental *Va* curves will fall between the line, *CF*, and the trough-shaped curve, *CRF*. As the diameter ratio approaches 1.00, the *Va* curve will approach *CF;* as it increases to large values, the *Va* curve will approach *CRF*. It will be observed that in Fig. 2, where the diameter ratio is 50.5, the *Va* curve approaches closely to *CRF*, and that in Figs. 2 and 3, where the diameter ratios are 6.3 and 8, respectively, the *Va* curves come about half-way between the curves for the limiting cases.

(12) Diameter Ratio To obtain quantitative information as to how the minimum *Va* for different two-size mixes depended on their diameter ratio, the *Va* values of a number of mixes containing 30% by true volume of the smaller particles were determined and are given in Table III.

TABLE III

MIXTURES OF TWO SIZES CONTAINING 30% FINE BY TRUE VOLUME

Material	Diameter ratio	Void (% by volume)	Va
Lead shot	1.000	36.9	1.585
" "	1.266	36.9	1.585
" "	1.460	36.1	1.570
" "	1.712	35.5	1.550
" "	2.110	34.7	1.535
" "	2.71	32.5	1.485
" "	4.13	28.6	1.405
Steel and lead shot	6.80	24.6	1.33
Sand	1.00	37.7	1.605
"	6.29	26.2	1.36
"	50.0	18.5	1.23

The data given in Table III are plotted in Fig. 5 where the abscissae give the ratio of the diameter of the coarse to the diameter of the fine particles and the ordinates of the Va curve give the values of Va for a 30% fine mixture. It will be seen that as the diameter ratio increases, the value of Va rapidly approaches the value 1.19 calculated for an infinite ratio.

(13) Conclusions When experimental Va curves for mixtures of rounded sand are plotted on a diagram of the type shown in Fig. 2, they give the line, *CF*, when the diameter ratio coarse: fine

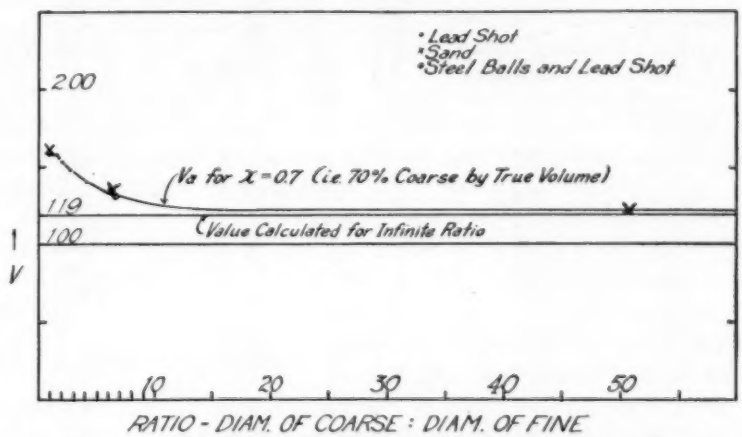

FIG. 5.—Packing in two-size systems: Effect of diameter ratio.

is unity and rapidly approach the shape, *CRF*, as the diameter ratio increases, the rate of approach being shown in Fig. 5.

V. Mixtures of Particles of Three Sizes

(14) Data The coarse, medium, and fine sands described in paragraph 9 were used in determining the value of Va for a series of mixes

containing three sizes of particles. The compositions of these mixes were so chosen that they gave a number of uniformly distributed points on the usual equilateral diagram. The compositions were expressed by means of x, y, and z, where x gives the true volume of coarse, y the true volume of medium, and z, the true volume of fine, in unit true volume of mix The values of Va obtained for the different mixes are given in Table IV. By combining Tables II and IV, data for the complete series of three-size mixes are obtained.

TABLE IV

THREE-SIZE SYSTEMS

x	y	z	Void (% by volume)	Va*
0.8	0.1	0.1	25.8	1.348
0.7	0.1	0.2	15.5	1.183
0.6	0.1	0.3	19.7	1.245
0.5	0.1	0.4	24.2	1.319
0.4	0.1	0.5	28.4	1.397
0.2	0.1	0.7	35.6	1.553
0.7	0.2	0.1	16.8	1.202
0.6	0.2	0.2	17.4	1.211
0.5	0.2	0.3	20.6	1.259
0.4	0.2	0.4	25.4	1.340
0.3	0.2	0.5	28.8	1.404
0.2	0.2	0.6	32.3	1.477
0.6	0.3	0.1	20.0	1.250
0.5	0.3	0.2	18.4	1.225
0.4	0.3	0.3	20.7	1.261
0.3	0.3	0.4	25.8	1.348
0.2	0.3	0.5	29.5	1.418
0.5	0.4	0.1	21.8	1.279
0.4	0.4	0.2	20.1	1.252
0.3	0.4	0.3	22.4	1.289
0.2	0.4	0.4	26.2	1.355
0.1	0.4	0.5	29.8	1.424
0.4	0.5	0.1	24.2	1.319
0.3	0.5	0.2	22.4	1.289
0.2	0.5	0.3	23.6	1.309
0.1	0.5	0.4	26.7	1.364
0.3	0.6	0.1	27.0	1.370
0.2	0.6	0.2	23.8	1.312
0.1	0.6	0.3	24.6	1.326
0.2	0.7	0.1	29.4	1.416
0.1	0.7	0.2	25.8	1.348
0.1	0.8	0.1	31.2	1.453

* The apparent volume occupied by unit true volume of mix when packed in the apparatus shown in Fig. 1.

(15) Limiting Cases In the case of three-size systems it will be more convenient to discuss limiting cases first and experimental surfaces later. As in the two-size system, the limiting cases

are (1) where the coarse, medium, and fine particles have the same diameter, and (2) where the coarse particles are very large in comparison with the medium particles and the medium particles are very large as compared with the fine particles. In Fig. 6, the equilateral triangle labelled coarse, medium, and fine provides a field for plotting compositions, and volumes are measured by means of perpendicular ordinates erected on the triangle.

If the points C, M, and F give the values of Va for the coarse, medium, and fine particles, respectively, then the Va surface for mixtures of coarse, medium, and fine for the limiting case where their diameters are equal will be the plane passing through C, M, and F. The Va surface for the other limiting case when the diameter ratios are infinitely large is the shaded surface formed by the three planes in Fig. 6. By joining the point C to the points where $V = O$ at the medium and fine corners of the triangle, F to the points where $V = 1.00$ at the coarse and medium corners, and M to the point $V = O$ at the fine corner and to the point $V = 1.00$ at the coarse corner, these three planes can be obtained graphically and give the binary minimum points O, N, and R. By joining O to the point $V = 1.00$ at the coarse corner, N to the point $V = O$ at the fine corner, and R to the point Q where the line joining C to $V = O$ at the medium corner cuts the line $V = 1.00$, the figure can be completed.

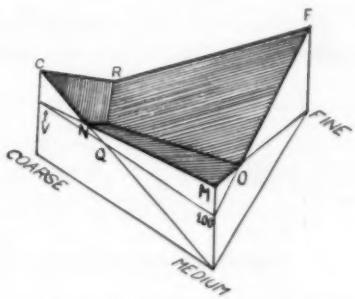

FIG. 6.—Packing in three-size systems: Calculated Va surface for very large diameter ratios.

The experimentally determined Va surfaces should fall between the surface formed by the single plane passing through C, M, and F and the surface formed by the shaded portions of the three planes shown in the figure.

(16) Analytical Expressions Since it is difficult to work with solid models, it is convenient to have analytical expressions for the planes described in the preceding paragraph. Since compositions have been expressed in terms of x, y, and z, where $x + y + z = 1$, these analytical expressions are relatively simple.

If the point C has the height a, M the height b, and F the height c, then the equation for the single plane through C, M, and F is

$$ax + by + cz = v \qquad (2)$$

where v is the height of the ordinate to a point in the plane.

If the three planes which form the minimum Va surface are labeled

C, M, and F in correspondence to the points through which they pass, then their equations are

$$v_C = ax \tag{3}$$

$$v_M = x + by \tag{4}$$

$$v_F = x + y + cz \tag{5}$$

where v_C, v_M, and v_F are the ordinates of points on the C, M, and F planes, respectively.

The minimum value of v which is obtained at the junction of the three planes, C, M, and F, is given by

$$v = \frac{abc}{ab + bc + ca - (a + b + c) + 1} \tag{6}$$

If the coarse, medium, and fine particles by themselves have the same value of Va, then $a = b = c$ and the minimum apparent volume is given by

$$v = \frac{a^3}{(1-a)^3 + a^3} \tag{7}$$

For $a = 1.605$, v is 1.057 and gives the value of Va which could be approached by packing coarse, medium, and fine sand with very large diameter ratios in the proportion $x = 0.66$, $y = 0.25$, and $z = 0.09$.

(17) Experimental Surface In order to compare the experimentally determined Va surface with the limiting surfaces derived in the preceding paragraphs, Fig. 7 was prepared. The contours shown in broken line in the figure are those of the experimental Va surface. The method used in plotting these contours may be of interest.

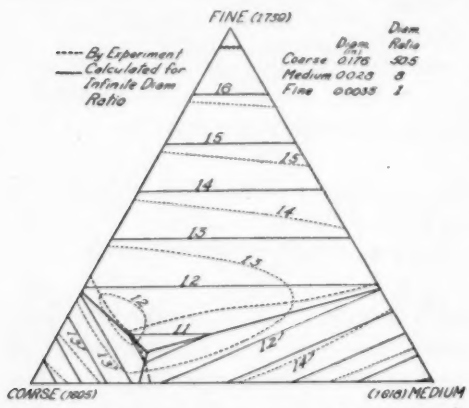

FIG. 7.—Packing in three-size systems: Comparison of experimental Va surface with that calculated for large diameter ratios.

Note: The numerals in this figure should show decimal point after first integer.

The experimental mixes were such that a number of straight lines could be drawn through the points representing their compositions on an equilateral triangle. For each such line a diagram similar to that shown in Fig. 2 was constructed and the compositions for values of Va equal to 1.1, 1.2, 1.3, etc., were found by interpolation. By plotting these compositions in Fig. 7 a large number of points for each contour line was obtained.

The contours shown in full line in Fig. 7 are those of the Va surface

calculated for the limiting case in which the coarse, medium, and fines differ infinitely in diameter. It will be noticed that the calculated and experimental contour lines agree very well along the coarse-fine side of the diagram where the diameter ratio is 50.5 and that they differ in other parts of the diagram where the diameter ratios are smaller by an amount which might be predicted from the curve in Fig. 5.

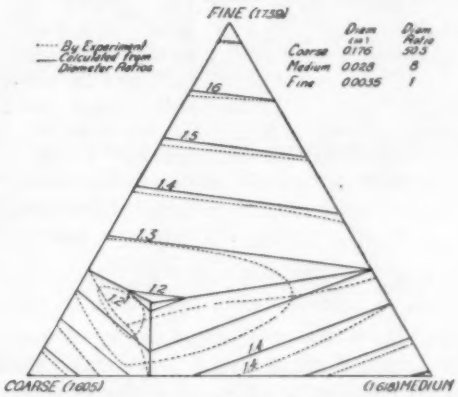

FIG. 8.—Packing in three-size systems: Comparison of experimental Va surface with that calculated from actual diameter ratios.

Note: The numerals in this figure should show decimal point after first integer.

If advantage is taken of the knowledge that the diameters of the coarse, medium, and fine were in the ratio 50.5:8:1, the contours shown in full line in Fig. 8 can be calculated, using Fig. 5 and linear interpolation. These agree very well with the experimentally determined contours shown in the same figure in broken line.

(18) Conclusions By an extension of the methods used in interpreting the data obtained with two-size systems, it is possible to calculate the corresponding limiting cases for three-size systems. Experimental values fall between the values for the limiting cases and differ from them by an amount which can be predicted from the diameter ratios of the particles used.

VI. Mixtures of Particles of Four or More Sizes

(19) Analytic Extension The symmetric nature of the analytic expressions given in paragraph 16 indicates a way in which the methods used in interpreting two- and three-size systems can be extended to include systems of four and more sizes of particles.

Let us suppose that n sizes of particles are designated 1, 2, 3..... n in order of increasing fineness. Let $x_1, x_2, x_3 \ldots\ldots x_n$ be used in expressing the composition by true volume of mixtures of these particles, the total true volume being unity, *i.e.*, $x_1 + x_2 + x_3 + \ldots\ldots x_n = 1$. Then if $a_1, a_2, a_3 \ldots\ldots a_n$ be the values of Va for each size when packed alone, the Va for any mixture in the limiting case in which no shrinkage occurs can be calculated from the equation

$$v = a_1x_1 + a_2x_2 \ldots\ldots a_nx_n \qquad (8)$$

For the other limiting case, in which the diameter ratios are infinite,

the Va of any mix can be calculated from the equation in the following which gives the largest value of v.

$$\begin{aligned} v_1 &= a_1 x_1 \\ v_2 &= x_1 + a_2 x_2 \\ v_3 &= x_1 + x_2 + a_3 x_3 \\ v_4 &= x_1 + x_2 + x_3 + a_4 x_4 \\ &\text{Etc.} \end{aligned} \tag{9}$$

By introducing into the above equations linear terms which depend on the diameter ratios involved, it should be possible to predict the value of Va for a mixture of particles of four or more diameters with approximately the accuracy shown in Fig. 8. By fitting curves to the experimental Va curves for two-size systems, closer agreement might be secured, but the gain in accuracy would probably be more than offset by the extra calculation involved.

It may be that further work will make it possible to calculate the packing properties of a mixture of particles from its sieve analysis. This possibility is now under investigation.

VII. Application to Ceramics

(20) Relation to Strength, Texture, Etc. With ceramic bodies which are made from a relatively inert aggregate, such as calcined clay, quartz, etc., and a flux or bond, such as clay, lime, etc., the density with which the aggregate packs may have a pronounced effect on the properties of the product. If a close-packing aggregate is obtained, the amount of bond can be reduced and the strength of the product will more nearly approach that of the aggregate material. The packing of the aggregate, therefore, may influence the strength, texture, refractoriness, color, and other properties of the product.

It should not be assumed, however, that the aggregate which gives the closest packing will necessarily give the best product. Other factors must be taken into consideration. The most important are (1) the solubility of the fine aggregate in the flux, (2) the relative strength of the aggregate and bond, (3) the importance of surface effects, etc. As an example, consider the relation between aggregate packing and the strength of a product. If the aggregate is relatively soluble in the bond, the fine particles in the aggregate will dissolve and change the packing of the aggregate. If the aggregate material is stronger than the bond, close packing will usually give high strength; if the bond is stronger than the aggregate, high strength will be associated with open packing. In some cases, the strength of a product depends to a considerable extent on the area of contact of the aggregate and bond. When this is true, the fine particles in the aggregate have a disproportionate effect on strength.

VIII. Summary

(21) Summary and Conclusions (1) The value of Va, the apparent volume per unit true volume, was determined for systems of one, two, and three sizes of roughly spherical particles when packed in an apparatus in which the packing of particles of uniform size and shape was independent of their diameter.

(2) For one-size systems Va was approximately 1.60.

(3) With two-size and three-size systems, the shape of the Va curve or surface depended on the diameter ratios. It could be calculated directly for the limiting cases in which the ratios were very large (approximately >15) or approached unity; for other ratios, the Va curve or surface could be calculated approximately by using an empirical relation between the minimum Va and the diameter ratio of two-size systems.

(4) The method of calculation was capable of extension to systems of four or more sizes.

(5) Calculated minimum values of Va for systems of one or more sizes of particles having very large diameter ratios, and packing individually to a Va of 1.605 (percentage void = 37.7), follow. The corresponding percentage voids are also given:

Number of sizes	Calculated minimum Va*	Calculated minimum percentage void
1	1.605	37.7
2	1.166	14.2
3	1.057	5.4
4	1.021	2.0
5	1.008	0.8

* The apparent volume occupied by unit true volume.

(6) In applying packing theory to ceramic problems the relative strength, colors, shrinkages, etc., of the aggregate and bond must be considered as well as the solubility of the aggregate in the bond and the importance of the surface area of the aggregate.

A DEVELOPMENT IN SPRAYING DEVICES[1]

By R. F. Grady, Jr.

ABSTRACT

A spraying machine is described which not only permits of accurate control, but possesses sufficient flexibility to produce all types of mottles.

Introduction

Mottling machines have come into use in the ceramic industry within the last ten years and are, therefore, still considered to be a new development in spray-coating equipment.

Mottled finishes have advantages over plain slip and glaze finishes which is evidenced by their rapidly increasing use. About 50% of the production of one terra cotta plant during the year 1927 called for mottled finishes.

Types of Machines Now in Use

Although many different kinds of machines are being used for this kind of work, they can be classified into two distinct types, according to the mechanical method used in the formation of the mottle. The first, and also the most satisfactory and generally used type, is the machine which breaks up a solid stream of coating material into drops by means of a plurality of air streams. This will be referred to as the air-mottling machine.

The other type of mottling machine is one which requires an electric motor to force the coating from the machine at definite intervals. This type is known as the electric-driven machine.

The finishes produced by these two types of machines differ widely, as does the handling of them. Thus it is necessary to have a double set of mottling machines always on hand in order to produce the general run of mottled finishes. This is not only inconvenient but requires that the sprayer be trained for the use of two machines rather than one.

Deficiencies in Machines Used

The Electric-Driven Machine

The motor is mounted on the frame of the machine, which functions with a pumping action caused by metal fingers pressing on the glazed-filled rubber tubes. This causes the glazing material to be expelled from the machine in a series of spurts.

Although this machine is so designed that the glazing material does not come in contact with the mechanism of the machine, in the practical operation of the machine the coating material gets back under the cover plates

[1] Presented at the Annual Meeting, American Ceramic Society, Toronto, Ont., February, 1930 (Terra Cotta Division).

and gradually cuts the bearings to pieces. The life of such a machine is rated in weeks of continuous service, at the end of which time, it must be returned to the manufacturers to be rebuilt.

This machine weighs approximately nine pounds without the necessary power cord or glaze lines. Its large size and weight makes it inconvenient to handle for any length of time.

The greatest disadvantage of this machine is its lack of flexibility and control. The machine will not produce small mottles, nor is it possible to regulate the quantities of material being ejected from either of the three outlets. This latter defect makes it difficult to reproduce mottles of the same color and texture from time to time. Under such conditions it is necessary that a close control be maintained not only of the specific gravity and Baumé reading but also on the apparent viscosity of each of the mottle components.

If the relative quantity of each mottle component is maintained constant, a range in variation of 5 to 6° Baumé reading of a glaze is permissible with no appreciable color variation resulting. If, however, it is impossible to maintain this ratio, a variation of several degrees Baumé reading is sufficient to cause excessive color variation. This has been found to be true whether using either the electric-driven machine, or the air-mottling machine.

The Air-Operated Mottling Machine

Unlike the electric-driven machine, the air machine is light in weight and simple in construction, very accurately controlled. It consists of three material tubes extending through an air box into the end of which are fitted removable tips. Around each material outlet is a series of air outlets, through which air from the air box is discharged. These air streams serve both to break up the emerging glaze steam and to carry the individual drops of glaze to the piece that is being sprayed. By shutting off the air and opening the glaze valve it is possible both to see and to adjust the proportion of each color being sprayed. There are no moving parts in this machine, and the only parts subject to wear are the outlet tips and the rubber cut-off tubes, which serve as valves. Both of these are replaceable in a short time.

With this type of machine the size of mottle produced is in general inversely proportional to the air pressure on the air box. Thus, if twenty-five pounds air pressure is used, a much smaller spot is produced than with ten pounds pressure. This machine cannot be used to produce mottles as large as those made by the electric-driven machine.

When a small air pressure is used the differences in the specific gravities of the slips and glazes causes the spots of the lighter material to fall on the piece being sprayed from six to eighteen inches ahead of the heavier spot. This causes an effect similar to rain drops falling on a dry side walk.

The decreased velocity of the drops is not sufficient to prevent them from running when falling on a vertical surface.

Properties of the Ideal Mottling Machine

(1) The machine must be light in weight, preferably less than two pounds.

(2) The machine must be simple in construction, with few or no moving parts.

(3) It must be flexible enough to produce both large and small mottles.

(4) It must be an easy matter to adjust and control the quantity of material emerging from each outlet.

A machine answering these four specifications would be of considerable value to the terra cotta industry. It would eliminate the necessity of having to use two machines to produce the general run of mottles.

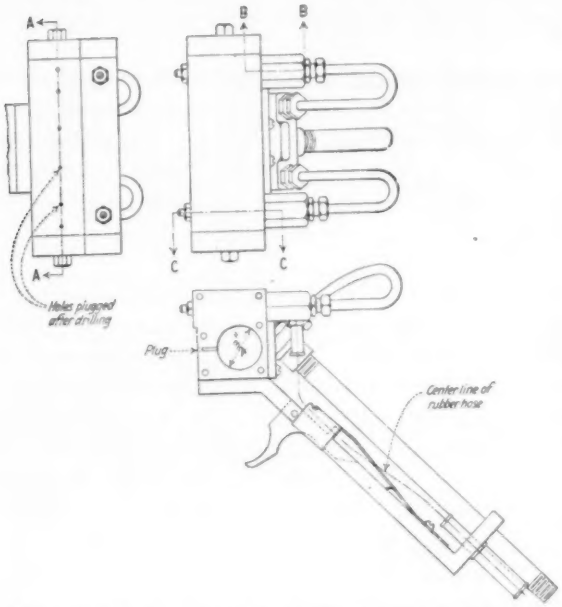

FIG. 1.—Top, side, and front views of completed machine.

Regardless of the source of power used to actuate the machine, whether air or electricity, the material must be ejected from the machine with sufficient velocity to cause the slugs of material to spread when they hit the piece being sprayed. This stream must be interrupted at definite and distinct intervals so that the stream will be broken into a series of individual slugs. The regularity of the spots should not be such that they produce a pattern. This is very noticeable in ashlar fields of terra cotta sprayed with the electric-driven machine. Some manufacturers go to the expense of applying an extra coat of mottles in order to break up the pattern that has been made in spraying the previous coats.

Designing a Flexible Mottling Machine

The use of electricity to actuate the mottling machine was not considered, due to the necessary complexity and weight. This left the use of air alone as the source of power.

Having decided on the source of power, the next requirement was the source of an interrupting or oscillatory action, for a material ejector. It was thought that if the exhaust from a simple valveless air motor could be used to eject the glazing material from the machine, a reliable and yet simple machine could be produced.

A machine of this type would be light in weight and yet subject to just as accurate control as is the air-mottling machine. The only moving part on such a machine would be the reciprocating piston, and as this would be inclosed and away from all slips and glazes, the wear upon the piston would be very slight.

This machine would, however, require that a check valve of positive action be placed in the air line between the exhaust port and the ejector; otherwise the glaze material might back up into the cylinder, causing a rapid deterioration of the motor.

FIG. 2.—Air filter.

An air motor having a $^3/_4$-inch diameter piston and $^3/_4$-inch stroke was built and fastened on to an air-mottling machine of the type previously described. The motor exhaust was fed into the regular glaze outlet tubes through "Vee" connections. This machine showed so much promise that it was redesigned with several radical changes in both the motor and glaze ejector system.

The greatest trouble experienced with the original machine was the difficulty in starting the motor. It was necessary to pound the end of the motor against the floor or wall to get it started. Changing the motor to permit more ease in starting proved to be quite an undertaking. Even those used to working with and repairing air motors could offer no encouragement. After considerable testing the reason for the difficulty in starting was determined. It proved to be due to the fact that air leaked past the piston and built up a pressure in the ends of the cylinder equivalent to the line pressure. Then it became necessary to move the piston past either of the two exhaust ports to start the motor.

After the cause of the trouble was determined it was a simple matter to find a remedy. This was accomplished by placing a push valve in both of the cylinder heads. This permitted the air to leak out of the end opened and the motor started instantly in the direction toward the end that was then at atmospheric pressure.

The amount of air exhausted from a motor of $^3/_4$-inch diameter piston and $^3/_4$-inch stroke is considerable. It was found to be sufficient to partly

atomize the glaze material. This atomizing effect was overcome by placing a small leak valve in the end plates adjacent to the starting valves. This leak valve is merely a plug through which extends an orifice of 0.022 inch in diameter. This plug can be easily removed and replaced. Thus a portion of the air compressed in the cylinder head is exhausted through the exhaust port and the remainder is exhausted through the leak valve in the cylinder head. Other functions of this leak valve will be discussed later.

A ball-bearing $^{9}/_{64}$ inch in diameter held against a polished seat by means

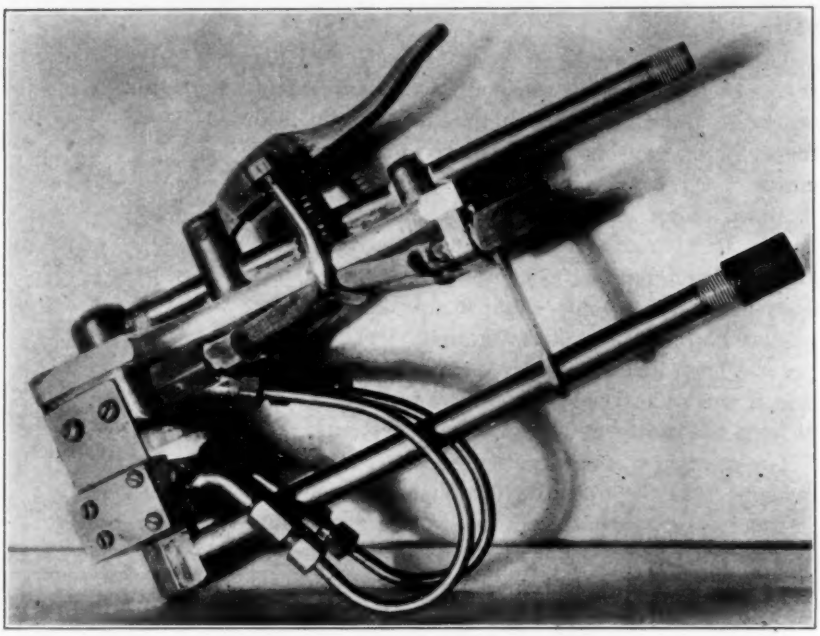

FIG. 3.—Side view of experimental machine.

of a fine coil spring serves as a check valve. These are placed within the cylinder block and the check valve retainers are fastened on to the air-supply tubes by means of small brass unions. The other end of the air-supply tubes terminate within the glaze well and extend to within $^{1}/_{4}$ inch of the glaze outlet tips. The glaze well is filled from the bottom directly from the glaze-supply tubes. The ejector was made in this manner to prevent the exhaust air from backing up into the glaze lines and preventing the proper flow of glazing material. This type ejector proved to be much more satisfactory than the one previously used.

Testing the Assembled Machine

The assembled machine weighed one pound and ten ounces without the air-or glaze-supply lines. The low weight is partly due to the liberal use of

aluminum and Major Metal. The latter is a new alloy which has the approximate specific gravity of aluminum but excels it in the resistance to wear when used as a bearing metal. After three months of continuous service the cylinder showed no measurable wear, yet the hard bronze piston was reduced 0.0015 inch in diameter.

The action of the check valves was questioned and so it was decided to test them under adverse conditions. The glaze lines were connected to a water hydrant and tested for leakage of water into the cylinder. Although the water pressure was sufficient to blow off the short connecting hose lines, no water was forced into the cylinder.

It was found that the air pressure could be varied from fifteen to thirty-five pounds and still permit the machine to function in the proper manner. Thirty-five pounds air pressure produced a spot as small as can be produced with the air-mottling machine, and fifteen pounds produced as large a spot as is produced with the electric-driven machine. If the size of the leak valves is varied, it is possible to produce a large spot of one color and a fine spot of another color at the same time. The ejector fed from the side with the smaller air-leak valve produces the smaller spot.

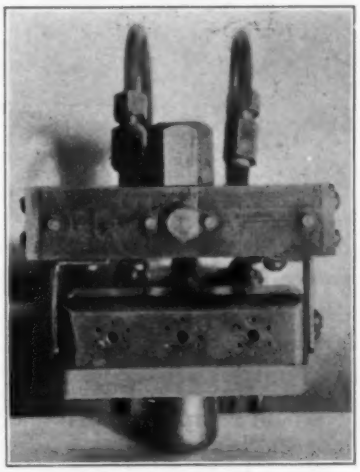

FIG. 4.—Front view of experimental machine.

As the glaze passes uninterruptedly through the machine in a continuous stream, when the air is shut off it is possible both to see and to adjust the ratio of each mottle component being applied. The emerging slugs of glaze or slip travel at such a velocity that they show no tendency to run when falling on a vertical surface.

Various sized tips have been tried, ranging in inside diameter from 0.037 to 0.125 inch. The only difference noticed was the rate of discharge of the material, and the size of spot produced; using tips with larger holes and higher air pressure, it is possible to produce the same size of spot as when using tips with smaller holes and lower air pressure. In all cases the cross-section area of one tip was made just twice the area of the other tip. This was done to produce mottled colors similar to those produced by both the air-mottling machine and the electric-driven machine. No trouble has been experienced in matching samples made by either of the two older type machines. It has been found to be impossible to differentiate between the material sprayed by either machine.

No attempt has so far been made to produce a mottling machine of this type with the provisions for spraying more than two colors at one time, as a large majority of the mottled colors produced are composed of only two colors. There is little doubt but that the air from either, or both exhausts, can be split and made to actuate two material ejectors. This would provide means for spraying four colors at one time, which is one color more than is being used at present for production work.

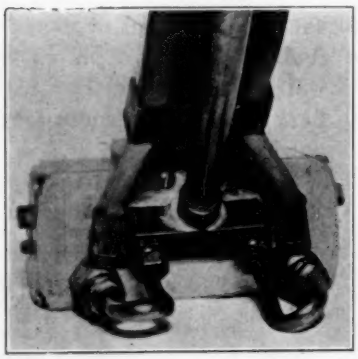

FIG. 5.—Rear view of the completed machine.

A machine of this type requires very clean air. The presence of a considerable quantity of oil or water in the air will cause the air-valve passages to become clogged and the motor to stop. Trouble of this type was later experienced during a spell of severe cold weather A filter, consisting of a six-inch cast-iron nipple fitted with caps on each end and filled with mineral wool, was placed in the air-supply line adjacent to the machine. This filtered the air sufficiently to prevent the recurrence of the trouble.

Conclusions

(1) A mottling machine has been made, weighing one pound and ten ounces, that is simple in construction, easy to handle, and fool-proof.

(2) It is so flexible that it is possible to match the mottled colors made by both the air-mottling machine and the electric-driven machine.

(3) The machine is subject to very accurate control and yet does not produce a pattern in the sprayed surface.

(4) The only moving part of the assembly is the piston which should give at least one year of service without attention.

THE NORTHWESTERN TERRA COTTA COMPANY
CHICAGO, ILLINOIS

CERAMIC ABSTRACTS

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Abrasives

Manufactured abrasives. F. L. NOBBS. *Ind. Chemist*, **64** [6], 183–84 (1930).—A modern silicon carbide furnace is a rectangular firebrick structure with electrodes at opposite ends. A typical charge consists of 56% of sand, 35% of petroleum coke, 7% of sawdust, and 2% of salt. The initial resistor charge in the core of the furnace is granular coke, and a current of 10,000 amp. is used. After interaction is complete the furnace is pulled down, the outer layer of partly reduced silica removed, and the silicon carbide crystals are broken up. The temperature range for the reaction is 1500 to 2200° and the probable equation $3Si + 2CO = 2SiC + SiO_2$. Silicon carbide is slowly oxidized in air at 1000 to 1350° and reacts with chlorine at 900° and above. It is not acted on by acids, but is attacked by fused alkalis. It has *d* 3.12 to 3.20, very high thermal conductivity, and low coefficient of expansion. Crystalline fused alumina (alundum, etc.), gives better results than silicon carbide for grinding materials of high tensile strength. It is prepared by treating bauxite in an electric furnace consisting of an unlined, water-cooled, cylindrical, steel shell. The impurities in the bauxite are reduced to ferrosilicon. Alundum has *d* 3.9, is almost as hard as silicon carbide, but has not so high a thermal conductivity. It is slightly soluble in hot acids. (*B.C.A.*)

Grinder equipped with air cleaner. ANON. *Abrasive Ind.*, **11** [8], 44 (1930).—A new heavy-duty grinder, placed on sale by Hammond Machinery Builders for continuous heavy tool grinding, is fitted with an air cleaner which supplies cool air to the motor windings and eliminates dirt and grit. E.P.R.

Portable air grinder. ANON. *Abrasive Ind.*, **11** [8], 44 (1930).—The Buckeye Portable Tool Co., Dayton, O., has a new, compact, portable air grinder, especially adapted for using small wheels, abrasive pencils, rotary files, etc. E.P.R.

Grinding chromium plate. ANON. *Abrasive Ind.*, **11** [8], 40–41 (1930).—Grinding of chromium-plated gages leaves minute wheel marks which soon wear away making the gage undersize. Lapping after grinding, or lapping only, is required. E.P.R.

Grinds spherical surfaces. ANON. *Abrasive Ind.*, **11** [8], 42 (1930).—Finishing of spherical work by the centerless method is accomplished by a special set-up. The grinding and regulating wheels are both trued radially for ball grinding. To generate a true sphere accurately on each ball, the regulating wheel is mounted on a special collet at an angle of 12° to the axis of the regulating wheel spindle. This produces a constantly varying inclination of the regulating wheel relative to the grinding-wheel axis as the regulating-wheel spindle revolves. Thus the face member works on the wobble-wheel principle. E.P.R.

Precision roll-grinding machine. ANON. *Engineering*, **129** [3353], 538–40 (1930). A.A.

Recommend light pressure in grinding tungsten-carbide tools. ANON. *Carboloy; Abrasive Ind.*, **11** [8], 32–33 (1930).—Tungsten carbide tools cannot be ground by the methods ordinarily followed in tool sharpening. Silicon carbide wheels bonded by a special process are necessary. Under no circumstances should the material in process of grinding be subjected to alternate heat and cold. For quality of the finish, grinding followed by lapping is recommended. Light pressures should be used; the wheel should not be crowded. E.P.R.

Bit grinder sharpens tungsten carbide. ANON. *Abrasive Ind.*, **11** [8], 44 (1930).—A direct motor-driven, tool-bit grinder developed especially for reconditioning the edges of tungsten-carbide tools has been designed by the Standard Electrical Tool Co., to increase ease in grinding control. Angle, rake, and cut may be set before starting to prevent unnecessary tool waste. E.P.R.

Engineers discuss abrasive problems. ANON. *Abrasive Ind.*, **11** [8], 31 (1930).—

The meeting of the A.S.M.E. was held recently in Detroit. Limitations of boring, reaming, burnishing, and broaching as finishing operations on cylindrical bores have led to the general use of abrasives for such work. The honing method of finishing bores has the advantages of speed, improved accuracy and finish, and low costs. The grinding mechanism consists usually of an expanding segmental wheel made up of a series of abrasive stones placed longitudinally upon the surface of a metal body with an adjusting means for expanding the stones to the walls of the cylinder being ground and for holding them under pressure against the wall, the grinding wheel being reciprocated and rotated simultaneously. Replies to a questionnaire sent out by the subcommittee on tungsten-carbide cutting materials of the A.S.M.E. give some information on current practice in grinding tungsten carbide. The replies indicated that tool grinding was done mostly by hand; a few companies reported using cutter grinder machines. E.P.R.

Expanding grinder offers refinements in finishing. J. W. HINDES AND JAMES G. YOUNG. *Abrasive Ind.*, **11** [8], 25–27 (1930).—Necessity for reduced production costs in internal grinding has brought about the use of the expanding grinding or so-called honing method. This method has the advantage of speed, accuracy, and high finish, combined with low cost, and makes possible precision grinding of long tubes, gun barrel rifling, and bores with ports, keyways, and relieved portions. (Abstracted from a paper before A.S.M.E. meeting, Detroit.) E.P.R.

Control of grinding variables. ANON. *Abrasive Ind.*, **11** [8], 30–31 (1930).—When the production of modern manufactured grinding wheels was begun in the 19th Century, the motive back of the replacement of the sandstone was greater uniformity in the structure of the grinding wheels, a harder abrasive, and finer control of the product. Manufacturing experience has shown that there are five variables in a grinding wheel which influence its grinding action: (1) kind of abrasive, (2) size of abrasive, (3) amount of abrasive, (4) kind of bond, and (5) strength of bond. Using natural abrasives was a primary step in eliminating soft spots, irregularities in grade of strength, and insufficient hardness. Substitution of the manufactured abrasives, aluminium oxide and silicon carbide, was the second advance by which it has been possible to control even the crystalline structure of the abrasive. A new method of manufacture is referred to as control of the volume structure of the wheel and means that all five variables are constant. E.P.R.

Wheel setting-up machine. ANON. *Abrasive Ind.*, **11** [8], 49–50 (1930).—A polishing wheel setting-up machine, developed and used by the General Spring Bumper Corp., was introduced recently. Illustrated. E.P.R.

New type wheel for buffing. ANON. *Brass World*, **26** [7], 185 (1930).—A new type of wheel for carrying an abrasive cloth for metal buffing by C. B. Hunt & Son, Salem, O., speeds up operations and reduces operating costs. Strips of abrasive cloth may be attached with or without metal end clips without removing wheel from spindle. E.P.R.

Simple tests determine characteristics of glue. T. R. TRUAX. *Abrasive Ind.*, **11** [8], 48–49 (1930).—Glue occupies the same relation to the set-up polishing wheel as the bond does to a grinding wheel. A polishing wheel is no better than the glue used. Bulletin, No. 1500, issued by the U. S. Dept. of Agriculture gives tests for animal glues, the kind used for setting-up polishing wheels. E.P.R.

How Ford finishes crankshafts. ANON. *Abrasive Ind.*, **11** [8], 18–22 (1930).—This article illustrates and describes the grinding methods followed at the Dearborn plant. Special grinding is supplemented by final honing and followed by close check for balances. E.P.R.

Exhaust system. ANON. *Abrasive Ind.*, **11** [8], 43 (1930).—The device is a dust-

exhausting system adapted to serve a disk-grinding machine at the plant of the Dust Recovering & Conveying Co., Cleveland. Illustrated. E.P.R.

Two-wheel job finishes fenders economically. ANON. *Abrasive Ind.*, **11** [8], 46–47 (1930).—Fender-finishing operations followed at the Cleveland division of the Hupp Motor Car Corp., are described. E.P.R.

Coating large abrasive belts. ANON. *Abrasive Ind.*, **11** [8], 47 (1930).—A method recommended by the Russell Mfg. Co., is simple and easily carried out. E.P.R.

Use new wheel marking system. ANON. *Abrasive Ind.*, **11** [8], 43 (1930).—Norton Co. is standardizing a new system of wheel markings to clarify for the consumer the symbols which designate wheel characteristics. E.P.R.

Safety secured in operation. FRED B. JACOBS. *Abrasive Ind.*, **11** [8], 23–24 (1930).—Safety precautions in the grinding wheel industry begin by testing the wheels and carefully packing them for shipment. Compared with other hazards, the grinding wheel ranks low as a cause of accidents. A few precautions that assure safety in grinding wheel operations are briefly outlined. E.P.R.

1929 abrasive production gains. ANON. *Abrasive Ind.*, **11** [8], 41 (1930).—The years of 1928 and 1929 show important gains in production of manufactured abrasives. Pumice is the natural abrasive that shows a gain. E.P.R.

Abrasive shipments decline slightly. E. B. MORSE. *Commerce Repts.*, **32**, 343 (1930).—Exports of abrasives declined in value by $630,806, or over 13%. Losses were noted in all classes. Shipments of abrasives go principally to the United Kingdom and Canada, and substantial quantities of artificial abrasives go to Australia, Germany, France, Sweden, Italy, Spain, and Japan. E.J.V.

BOOKLETS AND BULLETINS

Abrasives. ANON. *Chem. News*, **141** [3662], 391 (1930).—A brief outline of the monograph on abrasives by V. L. Eardley-Wilmot. For abstract of monograph see *Ceram. Abs.*, **9** [9], 696 (1930). G.R.S.

Tool grinding. ANON. *Abrasive Ind.*, **11** [8], 45 (1930).—A booklet by the Carborundum Co. discusses the characteristics of tungsten carbide, the grinding problem, and the proper makeup of abrasive wheels required. Photomicrographs show results of use of various abrasives. The booklet is a manual of procedure for grinding tungsten carbide. E.P.R.

Grinding machines. ANON. *Abrasive Ind.*, **11** [8], 45 (1930).—The Cincinnati Milling Machine Co., and the Cincinnati Grinders, Inc., have coöperated in publishing a 52-page catalog covering the standard line of machine tools manufactured by both companies. In addition to the descriptions and specifications in English, it also contains French and German dimensions and descriptions. E.P.R.

Polishing wheels. ANON. *Abrasive Ind.*, **11** [8], 45 (1930).—The Allied Industrial Products Co., Chicago, has issued a catalog containing useful information of interest to all engaged in polishing and buffing. E.P.R.

PATENTS

Making abrasive disks. HARRY C. MARTIN. U. S. 17,739, July 22, 1930 (reissue). The method of making abrasive disks which consists in mixing abrasive grains with shellac in the approximate proportions of 9 to 1 parts, spreading the material in a suitable mold upon a backing, placing the mold in a melting oven and bringing its contents to a temperature sufficient to soften the shellac, then applying a pressure to the abrasive material sufficient to agglomerate it but not to reduce the porosity of the finished disk below about 36%, and then baking the article so formed, substantially as described.

Making abrasive disks. HARRY C. MARTIN. U. S. 17,740, July 22, 1930 (reissue).

The method of making abrasive disks, which consists in mixing abrasive grains with a synthetic resinous bonding material, spreading the mixture in a suitable mold upon a backing and applying an agglomerating pressure to shape the disk, and then baking the disk so formed, the abrasive grains and the bonding material being so proportioned and the agglomerating pressure being so limited as to give the abrading portion of the disk an apparent density of not over about 2.3 g. per cu. cm.

Truing attachment for grinding machines. SIDNEY C. PROBERT AND ROBERT E. SPURR. U. S. 1,770,711, July 15, 1930. A grinding machine having in combination a grinding wheel, a truing tool for one face of the wheel, another truing tool for another face of the wheel, and a single carriage for the tools capable of moving in directions, respectively, parallel to the faces of the wheel which are to be trued, the tools being connected to the carriage in such relation that one tool is brought into operative contact with its face of the wheel at the end of the movement by which the other tool is caused to true its face of the wheel.

Grinder for concave saw teeth. EDWARD P. ARMSTRONG AND ROBERT S. JACKSON. U. S. 1,771,602, July 29, 1930. A saw-tooth grinder comprising a frame adapted to be affixed to a support holding a circular saw, an arbor journaled in the frame and longitudinally reciprocable in the plane of the saw, the axis of rotation of the arbor if produced representing a chord of the circle described by the saw blade, means for rotating the arbor, a cylindrical grinder wheel carried by the arbor, adapted to be inserted in the throats of the teeth of the saw blade, respectively, whereby the cutting face of the saw tooth operated upon will be concaved to represent a section of a cylinder whose axis lies in the plane of the saw and is parallel with the face.

Grinding machine. JOHN BATH. U. S. 1,771,948, July 29, 1930. In a grinding machine, a work table mounted for longitudinal movement, a double tail center secured to the table at an intermediate point, a pair of head centers nonrotatably mounted at the ends of the table and each yieldingly slidable toward and from the tail centers, separate work-driving mechanism associated with each of the head centers, and means engaging the mechanism to yieldingly withdraw the head centers independently of the driving mechanism.

Cylinder grinder. MARSDEN C. HUTTO. U. S. 1,772,045, Aug. 5, 1930. In a cylinder grinder, the combination of a body member, a pair of opposing cones mounted on the body member, means for adjusting the cones relatively to each other lengthwise of the body member, a plurality of longitudinal supporting bars arranged in an annular row around the periphery of the body member, sliding pins extending inwardly from each of the bars and guided for radial movement on the body member and engaged at their inner ends with the cones, each of the bars being provided with a pair of apertures which are arranged lengthwise in line, a stone holder provided with a pair of retaining pins extending into each pair of apertures on the bars, set screws mounted on the bars and each engaging with one of the retaining pins, and a grinding stone mounted on the stone holders.

Gear-grinding machine. OLIVER G. SIMMONS. U. S. 1,772,271, Aug. 5, 1930. A gear-generating machine comprising a cutting element, a work carriage mounted for linear reciprocating movement transversely of the plane of the cutting element, a rotary work spindle mounted on the carriage and extending transversely of the direction of linear movement of the carriage, an abutment fixed with respect to the carriage, and a cam mounted on the work spindle to turn therewith, the cam having a peripheral abutment-engaging face contacting with the abutment closely adjacent the plane of movement of the spindle, the engaging face being formed on a spiral curve such that, upon a turning movement of the spindle, a linear movement is imparted to the carriage at a speed proportional to the speed of angular movement of the spindle.

Grinding machine. CARL G. FLYGARE. U. S. 1,772,345, Aug. 5, 1930. A grinding machine comprising a grinding wheel and a mounting therefor, a truing mechanism secured upon the mounting and including a movable slide having a hollow housing, a forming bar mounted in fixed relation to the axis of the wheel, a sleeve freely slidable within the housing slide to move relative thereto toward the wheel and carrying a follower arranged for operative association with the forming bar, a dresser mounted within the sleeve, a precision feed mechanism for feeding the dresser relative to the sleeve, and means for actuating the slide to move the dresser across the periphery of the wheel.

Grinding lens surfaces. W. W. TRIGGS. Brit. 328,849, July 2, 1930. A machine for grinding both surfaces of a lens, etc., simultaneously.

Grinding screw-cutting taps. H. LINDNER. Brit. 328,900, July 2, 1930. To facilitate grinding, screw-taps are formed with alternate teeth on each land missing, the teeth on adjacent lands being staggered. The wheel can be dressed without risk of fracture. The wheel may be multi-ribbed to grind all the teeth on one land simultaneously. Several methods of grinding with a wheel having a single rib are described.

Grinding screw-threads. H. LINDNER. Brit. 329,241, July 9, 1930. Screw-threads are formed by grinding roughly with a multi-ribbed grinding disk having its axis parallel to that of the screw, and finishing the thread by means of a single ribbed grinding disk tilted in conformity with the inclination of the thread. In order to back-off taps after rough grinding, either disk may be used, the disk being fed toward or away from the axis of the tap as grinding proceeds from one edge to the other of each land.

Grinding and polishing. H. R. STRATFORD. Brit. 329,323, July 9, 1930. An abrasive tool for grinding and polishing metal, wood, and other panels, etc.

Grinding screw-threads. H. LINDNER. Brit. 329,595, July 16, 1930. A roller for grinding screw-threads is cylindrical in shape, but in use has its axis inclined to that of the work, the ribs being cut symmetrically with respect to a line perpendicular to the axis of the work. The truing tool is similarly formed.

Grinding watch glasses, etc. P. REUSSER. Brit. 329,676, July 16, 1930. In a machine for grinding the edges of watch glasses, etc., the work-holder is mounted on a vertical spindle which is carried by a slide and is indexed by Geneva mechanism operated through a disengageable worm drive when glasses of polygonal shapes are to be treated.

Grinding files. H. LINDNER. Brit. 330,170, July 23, 1930. Files have the teeth formed thereon by a grinding wheel having thereon cutting profiles corresponding to the shape of the teeth. The wheel may be of the same length as the file blank which is passed beneath the wheel; the number of profiles on the wheel may be such as to cut all of the teeth on one passage of the blank or to cut alternate teeth on one passage. The wheel may be of conical form to produce undercut teeth, or may be of concave form with a straight portion and a curved portion, so as to cut bowed or tapered files. The plane surface of the profiled parts of the wheel may be inclined to the direction of movement of the file during the grinding. The wheels are trued by a profiled roller of tungsten, cobalt alloy, etc., and in the case of the conical wheel, the truing roller is conical and is in several independently rotatable sections.

Art and Archaeology

Art in ceramics. EDMUND DEF. CURTIS. *Clay-Worker*, **94** [1], 25 (1930).—C. commented on the abuse of the term of art as applied to industrial production and pointed out the manner of leading up to the really artistic product from the technical side. The industry is capable of remarkable technical achievements, the buying public

is trained to value the fine arts, and in between is the weak system of introducing quality of design. It is the system that is at fault; otherwise the design and art quality would be under the control and leadership of producing plants. E.J.V.

Introduction to the theory of colors of Wilhelm Ostwald. J. WOLF. *Repts. Czechoslo. Ceram. Soc.*, **6** [1–2], 24 (1929); *Sprechsaal*, **63** [30], 567 (1930).—The Wilhelm Ostwald theory of colors classifies every color specifically. W. defines the expressions "color" and "coloring matter;" non variegated and variegated colors are distinguished; the first form a continuous, simple series of grays beginning with white and terminating in black. The subjects, luminosity, white, black, gray, and variegated, are explained. The preparation of equally distant stages of gray must follow a geometric progression because they can be perceived only by a geometrical gradation of luminosity. A gray is designated according to the fraction of light which it reflects, expressed in hundredths. The color tone of variegated colors can be changed by varying the white, the black, or the gray contents. The color tone is the property of variegated colors to which the name of the color refers. Pure colors have a definite color tone and do not contain non-variegated constituents. The color tones form a continuous series in the form of a circle and there are 8 main colors: yellow is the lightest, then follows orange, red, violet, u-blue, ice blue, sea green, and foliage green. Contrasting colors when mixed produce pure gray: primary colo s are yellow, red, u-blue, and sea green. The standard color tones use three tones of the main colors which are numbered from 1 to 24; for finer degrees each interval is divided into 10 parts and these are indicated by decimal fractions. Additions of white to the pure colors give clear light colors; of black, clear dark colors. Cloudy colors are obtained by mixing pure colors with white and black. The color equation for cloudy colors is: $r + w + s = 100$, where r is the content of pure colors, w, of white, and s, of black. One or two of the components can be zero. In colors with white predominating large quantities of black are only slightly perceptible, while very small quantities of white in black lighten the color considerably. In an equal color-tone triangle the sides are formed of white, black, and gray or equally pure colors. There are 24 equal color-tone triangles, containing 672 color standards and with the additional 8 non-variegated colors, a total of 680. All the colors are collected in a color body, a double cone, with a common axle formed by the gray. White is at the top, and black at the bottom, and at the circumference are the full colors. Illustrated. M.V.K.

Sprayed molten metal coating process. R. L. BINDER. *Jour. Frank. Inst.*, **210** [2], 173–217 (1930).—A comprehensive description is given of MetaLayer and the sprayed molten metal coating process. Illustrated. M.A.B.

Lighting fixtures that embody art. ANON. *Ceram. Ind.*, **15** [2], 172–73 (1930).—A discussion of the use of glass in decorative and scientifically correct lighting fixtures is presented. W.W.M.

The artist's new teacher. DOUGLAS C. MCMURTRIE. *Rotarian*, pp. 9–11 (June, 1930); *Design in Ind.*, p. 3 (1930).—The artist of today looks to the engineer for inspiration and guidance in seeking sound principles of design. This is an age of steel. Who designed the modern locomotive? In the artist's sense, no one did. Proportions of one part to the other have been determined by the effort to generate the greatest power and speed with the least coal consumption. No other considerations are of importance.

Turquoise glazes for art pottery. W. HENZE. *Keram. Rund.*, **36**, 821 (1928); for abstract see *Ceram. Abs.*, **9** [2], 81 (1930). H.I.

Old English glasses. III. Drinking glasses with plain stems. FRANCIS BUCKLEY. *Glass*, **7** [6], 241–43 (1930); for Parts I and II see *Ceram. Abs.*, **9** [9], 703 (1930). H.W.A.

What is Doulton ware? CARL G. BEEDE. *Christian Sci. Mon.*, **22** [198], 9 (1930).—Doulton ware is the product of a pottery established by John Doulton at Vauxhall, England, in 1815. The body colors of their product were bronze, green, brown, gray, chocolate, and white. These colors could stand the heat of salt-glaze kilns, or could be used as "dry" bodies on which their famous decorations could be used. The first Doulton ware was completed in one firing, a method rarely used today. They also made a fine salt-glazed stoneware with molded ornaments or decorations, such as tobies, hunting jugs, bellarmines, and "Egyptian" tankards. Their "Carrara" ware is stoneware modeled in the plastic state, covered with crystalline enamel, finished in colors and gold. Another product was "Marqueterie" ware. A terra cotta of biscuit body, decorated by paintings and fired underglaze, was called Lambeth faience. It was used for vases and panels. Most of this ware is unique, never having been reproduced, and each one bears a monogram or mark of the artist. E.J.V.

Dresden china in old and new forms. ANON. *Arts and Dec.*, **33** [3], 33 (1930).—Illustrations of figures and animal forms. E.B.H.

Essen stained glass. ANON. *Christian Sci. Mon.*, **22** [169], 6 (1930).—W. Hallerman of Essen has an exhibition of stained glass and designs for stained glass suitable for churches, public buildings, and private houses at the Hamburg Museum of Arts and Crafts. Some of the exhibits are described. E.J.V.

French glassmakers increasing use of sand jet. ANON. *Ceram. Ind.*, **15** [1], 88 (1930).—Sand jets of various types are being used extensively in France to decorate glass objects. This method is being used to replace the chemical method of polishing glass, as well as for engraving designs and cutting. W.W.M.

Visit to Etruria, birthplace of the Wedgwood Potteries. LAURA LORENSON. *Arts and Dec.*, **33** [4], 62 (1930).—At the pottery of Josiah Wedgwood and Sons, established 200 years ago may be seen Wedgwood's experiment book and some original designs and molds, many of which are still in use. The black basalt was evolved from the black ware produced at Staffordshire for some time. Large tablets and vases in jasper ware were possible without great loss in firing only after the invention of the jasper dip, a surface coating. Insets of black basalt and jasper were used by contemporary jewelers, architects, and furniture makers. E.B.H.

Enamels of Limoges and Battersea. ANON. *Christian Sci. Mon.*, **22** [210], 9 (1930).—A group of 18 little plaques of Limoges enamel, depicting scenes in the life of Jesus, made about 1550 by Jean Penicaud, II, are now in the South Kensington Museum. They were bought for $4000 in 1860, after having been owned by various persons and having sold for as little as $125. E.J.V.

Porcelain of 18th Century exhibited. CHARLOTTE STEINBRUCKER. *Sprechsaal*, **63** [27], 506 (1930).—A great number of articles and valuable objects of porcelain made in the 18th and 19th Centuries to be seen in the exhibition of "Old Berlin," in that city, are described. M.V.K.

International exhibition of glass and rugs. ANON. *Creative Art*, pp. 352–55 (May, 1930); *Design in Ind.*, p. 4 (1930); for abstract see *Ceram. Abs.*, **9** [4], 253 (1930).

Summer exhibitions at Metropolitan Museum. ANON. *Amer. Mag. Art*, **21** [8], 457 (1930).—The museum has recently received the gift of a stained glass window by John La Farge. Subject: peonies blown in the wind. E.B.H.

Jugoslav exhibition in London. ANON. *Illus. London News*, **176**, 793 (1930).—Held in London in May at the National Gallery, Millbank (Tate), and said to be the most representative of Jugoslav art ever held in the West. Among the illustrations is a terra cotta "Two Workers" by Tine Kos. H.H.S.

Glassmaking and ceramics at the Exposition of Liége, 1930. ANON. *Rev. belge ind. verrières*, **1**, 99–101 (1930). A.J.M.

Old Mexican arts on exhibition. ANON. *Christian Sci. Mon.*, **22** [204], 8 (1930).—A collection of old Mexican pottery being exhibited in the U.S. is described. This exhibit is the first one showing the essentially Mexican old and modern art as distinctive from the Spanish. Illustrated. E.J.V.

Copenhagen's Royal Porcelain gift to Iceland. ANON. *Christian Sci. Mon.*, **22** [215], 3 (1930).—In commemoration of its 1000-year festival Iceland was presented by the Danish Parliament with a 65 cm. high vase of Royal Porcelain, executed by Benjamin Olsen. Three views, representing the Thingvellir Plain, the Parliament House at Rejkjavik, and Copenhagen Harbor, are executed in cobalt, jade, and ochre on the vase. Illustrated. E.J.V.

Spanish-Mexican tile. A. R. R. *Christian Sci. Mon.*, **22** [169], 9 (1930).—The making of tile was brought into Spain by the Arabs. The oldest tile in Spain are at the Palace of the Alhambra, Granada, and are of the 14th Century. The earliest account of their manufacture is found in a letter, probably of the date 1422, which requests "azulejos" of different colors, black, white, yellow, and green be sent, presumably for a convent in Palencia. Tile-making attained great importance in Spain in the Middle Ages and it remains one of the established industries of that country today. The introduction of Italian art into Spain at the beginning of the 16th Century had the effect of setting up two schools, one keeping to the traditional designs and colors and the other in the use of shaded colors, somewhat after the Italian majolica. The Spanish, when invading Mexico in the 17th Century, brought to that country improved methods of pottery-making. The Mexicans were already decorating clay ornaments in a crude way, but they were taught how to produce the glaze used in making the old majolica of Spain. This industry has been revived in Mexico through the efforts of B. A. Whalen. The same materials, colors, and methods are being used as were used in making the original ware. There are five colors: a deep, rich, brownish red, blue, green, yellow, and black, which is used only to outline and accentuate a design. The biscuit is cured in a dark room by gradually moving it to the light. After being subjected to the light for a certain time, it is moved into the sun and dried until thoroughly cured. Before being painted it is dried in the oven. A glaze is then applied, which dries very rapidly. Over that the design is painted. The tile are placed in the oven with stilts separating the pieces. The design is painted on free-hand with no other aid than a painting wheel operated by foot, similar to a potter's wheel. This pottery though modern in manufacture is but a continuation of old pieces in form, design, and coloring. The formula of the old colors remains the secret of the original potters as in other branches of the art. E.J.V.

The "Lowestoft" fallacy. MABEL M. SWAN. *Christian Sci. Mon.*, **22** [198], 9 (1930).—The term Lowestoft, as applied to Chinese porcelain, is a misuse, blamed on Chaffers. A small china factory was established in Lowestoft in the middle of the 18th Century, but it manufactured only soft-paste porcelain of an inferior quality, often decorated with Chinese patterns. Fragments unearthed while excavating on the location of the old Lowestoft factory proved to be of an artificial, fritted, soft-paste porcelain, in composition very similar to that of Bow. There was no evidence that hard-paste porcelain, which the Oriental sort is, had ever been made at Lowestoft. Chinese or Oriental porcelain had been firmly christened "Lowestoft," by which name it is known today. A distinction should be made between "English Lowestoft," and "Chinese Lowestoft." Some museums call the Chinese porcelain "Oriental Lowestoft" or even "so-called Lowestoft." The color of the glaze of English Lowestoft is a pale bluish color, while the Chinese always has a greenish tinge. On the English Lowestoft, all lids of tea pots, basins, etc., were glazed all over the flange and not left bare as in the case of the Chinese Lowestoft. Illustrated. E.J.V.

Colored laminated glass for walls and floor of bathroom. ANON. *Nat. Glass Budget*, **46** [13], 14 (1930); *Amer. Glass Rev.*, **49** [44], 27–29 (1930).—The American Window Glass Co. is exhibiting "Tintaglass" in the Architects' & Builders' Exchange, Pittsburgh. It is used on the walls, floors, and as shelving of bathrooms. Six colors are used. Rose, orchid, and turquoise are combined in one pattern with satin gray on one wall of the room. On another wall the lavender and emerald green are used in a different arrangement. An arrangement with jet black for trimming is used on the third wall. E.P.R.

Fall lines in glassware. ANON. *Pottery, Glass & Brass Salesman*, **41** [21], 15 (1930).—(1) The Skinner-Hill Co. is offering a line of Chelsea figure reproductions in the form of book ends. Old English figures as well as modernistic subjects are depicted. High class European ware is used. (2) Manning, Bowman & Co. is showing synchronous motor clocks in special designs for boudoirs, living rooms, and kitchens. (3) The A. E. Hall Pottery Co. has a new type of cereal set. The legends are in raised letters and choice of color effects is offered. These include white, yellow, green, and blue. (4) Lazarus and Rosenfeld are showing a variety of Italian pottery and marble articles to retail for a dollar. The ware is a deep ivory color verging on the biege and is of the peasant pottery description. (5) The Salem China Co. are featuring a new line of dinnerware in a peach shade. Bright tones are used in the decoration which is principally in the form of floral sprays. E.P.R.

New York offerings in glassware. ANON. *Pottery, Glass & Brass Salesman*, **42** [1], 11 (1930).—(1) Edwin Bennett Pottery Co. is showing a new rich ivory-toned body decorated with hand-painted designs. (2) The Myott-Tharaud Corp. has four new patterns, only one of which is completed, known as the "Rosalie," a British ceramic production; the center is of light ivory on a wide portion of deep ivory with a band in light ivory at the edge. Decorations are in floral clusters in the green tone. (3) Fred C. Reimer Co. has new designs from the old Furstenberg factory in Germany. The "Maryland" is an outstanding shape in this line and is produced on an ivory body. Tulips are set in a base of green foliage in natural colors softened to pastel tints. A new decorative treatment is used on the Chippendale order shown on the old "Brunswick" shape. This is on an ivory body and is a combination of festoons and scroll motifs, conventionalized in blue and green. E.P.R.

New glassware. ANON. *Pottery, Glass & Brass Salesman*, **41** [25], 12 (1930).—(1) Fostoria Glass Co. has recently introduced a new dinnerware of the square variety, also two new lines of stemware to go with the dinner service. Practically any color combination is obtainable. Diamond cutting on the round-footed line is a particular feature. (2) Maddock & Miller has outstanding displays in the "Florentine" line of embossed ware which is on the della Robbia order, with its motifs of fruits and flowers in pink, green, blue, and black. (3) The Liberty Works has produced a new etched decorative treatment known as the "Chameleon." The etching is known as "the wiped-out" description. An excellent effect is obtained with blue color on green glass. E.P.R.

New glassware designs. ANON. *Pottery, Glass & Brass Salesman*, **41** [22], 23 (1930).—(1) Bartlett-Collins Co. is showing a new glassware with a dusted-on decoration giving the appearance of an etching, and is combined with punties cut in floral form. (2) Basket Importing Co. has, among the latest novelties, cactus bowls. (3) A. H. Heisey & Co. has several new patterns in glass tableware and specialties. A scroll-like treatment is an outstanding feature of this line, shown in crystal together with the four famous Heisey colors, "Moonbeam," "Flamingo," "Saharra," and "Alexandrite." (4) Bonita Glass Corp. has two new deep plate etched patterns on a full range of tableware and fancy items. (5) Frank L. Van Deman & Son recently introduced

the "Black Forest Glass" which applies to a treatment in deep-plate etching used band form on a variety of items in black glass. The decorations depict forests and hunting scenes. Much of the ware is trimmed with silver. (6) The Earl W. Newton & Assn. is showing a charming line of rock crystal cutting. E.P.R.

Glassware show rooms. ANON. *Pottery, Glass & Brass Salesman*, **41** [20], 23 (1930).—(1) Edmondson Warren, Inc., is featuring a new decorative treatment effective on crystal glass suggestive of the modern French school shown in two-color combination mainly. The treatment has the effect of enamel work but is done by special process. (2) Otto Goetz, Inc., has a new line imported from Germany and Czechoslovakia, among which is the "Amphora" ware. The main body is rough like stoneware with figures done in bright colors in high glazes. The "Amphora" is potted and decorated by hand. Another line is the "Eichwald" ware which is characterized by a high glaze and bright contrasting colors. There are also some new items in the Gouda ware from Holland. (3) DeLux Decorating Works has some new designs for china, and decorations are extensively in gold, both flat and raised; there are some shades of blue other than cobalt. (4) Geo. Borgfeldt & Co. is offering a line of black-footed stem ware similar to an old English shape. (5) Leon A. Anthony has many new cut glassware items among which is the "Mystic" having a floral pattern with the floral motifs relieved by geometric figures. (6) Tomby China Corp. has received items in "Duchess" china made by Lorenz Hutschenreuther concern of Bavaria. E.P.R.

Colored glassware. ANON. *Pottery, Glass & Brass Salesman*, **41** [22], 13 (1930).—(1) Stern Bros. is showing dinette sets in the black and green flower basket design on ivory English earthenware. Another pattern is the "Indian tree" in rose and green. A third set is adorned with the "Gay Gladiolus" design on a new square American earthenware. (2) Woodward & Lothrop has a 32-piece open-stock porcelain cottage set in yellow glaze with floral design. (3) T. Eaton & Co., Ltd., is offering specials in china, in a 96-piece Limoges dinner service. The patterns are on translucent bodies of Limoges china with rose sprays and edges finished with a gold line. E.P.R.

Seasonal specialties in glassware. ANON. *Pottery, Glass & Brass Salesman*, **41** [19], 23 (1930).—(1) Morimura Bros., Inc., is showing a new "Imperial" shape with a wide variety of decorations. Gold is used to some extent. (2) E. B. Dickinson, Inc., is showing a new stippled effect treatment in underglaze decoration in a honey color. Decorations are printed under the glaze and require no further ornamentation than a colored edged line. Several colors are available. E.P.R.

Distinctive glass and chinaware. ANON. *Pottery, Glass & Brass Salesman*, **41** [26], 11 (1930).—(1) Duncan & Miller Glass Co. has two new designs in tumblers made both in color and in crystal. The shape is Georgian, characterized by corduroy effect in crystal, green, amber, and rose. (2) The Lotus Glass Co. has produced a line of decorative black glass with a heavy deposit of silver in unique design. (3) Heinrich and Winterling has a dinnerware treatment from Bavaria. The decoration consists of coin-gold edge lines with gold decorative handles and gold tracery around the knob, and is shown on the "Bella" octagon shape. Henry Bigart has a line of fancy and staple mirrors. E.P.R.

China and glassware for fall. ANON. *Pottery, Glass & Brass Salesman*, **41** [24], 23 (1930).—(1) John Maddock & Sons, Ltd., has brought out a new shape known as the "Centenary." It is roughly a square shape and the corners are cut off and slightly indented to give a fanciful effect. There are no handles, while the knob is low and square. The shape is brought out in the "Royal Ivory" with new decorations. (2) The Continental Ceramics Corp. has received from Bavaria a new pattern known as the "Columbia." It is shown against an ivory fond border. The ground lay is of a golden yellow on which is a blue scroll enlivened by flowers in all colors. (3) Koscherak

Bros. has received from Europe a new line of French glass novelties, mounted in bronze. The glass is adorned with embossed figures and is obtainable in crystal, Rose du Barry, apricot, and cream color. E.P.R.

Stone Age workshop found in England. L. McL. MANN. *Morning Post*, May 14 (1930).—Building operations in Surrey, have disclosed quantities of flints, cores, and implements which indicate the existence of a workshop. A fireplace containing charred turf or moss was found. H.H.S.

Art treasures from a newly-found catacomb. FRANCESCO FORNARI. *Illus. London News*, **176**, 720–21 (1930).—A catacomb of the 4th Century A. D. has been found in Rome by the Pontifical Commission, and has received the name of The Widowers from the number of tombs dedicated to the memory of wives. The gems of art include decorated glass plates, statuettes, terra cotta lamps, etc. Illustrated. H.H.S.

Eighth-Century mosaics from Damascus. EUSTACHE DE LOREY. *Illus. London News*, **176**, 732 (1930).—Colored reproductions of mosaics found in a mosque which was formerly the Byzantine church of St. John. See also *Ceram. Abs.*, 9 [1], 12 (1930). H.H.S.

New aspects of Byzantine art. STANLEY CASSON. *Discovery*, **11**, 141 (1930).—Since the War, Turkish authorities have afforded every courtesy to foreign archaeologists. The new discoveries made in Constantinople rank as the most important in recent years. H.H.S.

Chinese pottery between Han and T'ang. WILLIAM KING. *Int. Studio*, **96** [398], 32–37 (1930).—Owing to the efforts of R. L. Hobson of the British Museum, many Chinese pottery treasures must change their labels from Han and T'ang to those of an intermediate period (220 to 680 A. D.). One of the finest examples is a mortuary lamp made in three pieces whose long years of burial have given the glaze a supremely beautiful iridescent sheen. Another burial vase has round the middle a hunting scene painted over white slip in red and black unfired pigments, one of the most important documents in early Chinese painting. One jar having an olive brown glaze shows a band of turquoise blue unexpectedly colorful for the period. Ethnographers approximate this period with the American Indian. Two female figures, 32 inches high, are among the greater ceramic wonders of the world, both in modeling and in painting. E.B.H.

Antique china: fine examples of Chinese porcelain and modern china in striking designs. ANON. *Illus. London News*, pp. 644–45 (April 12, 1930); *Design in Ind.*, p. 3 (1930).—Fourteen designs, antique and modern, tell their own story.

Chinese porcelain. ANON. *Christian Sci. Mon.*, **22** [216], 11 (1930).—Among the beautiful and familiar of all types of Chinese porcelain are the oviform jars of underglaze blue that show a design of plum blossoms in white. Darker lines which suggest crackling in the blue ground are intended to represent the breaking and melting ice at the end of winter, as the plum blossom represents the return of spring. The best of the jars in blue and white porcelain date from the first twenty years of the 18th Century. They have been more imitated, both by Chinese and by western workmen, than any other of the forms struck out in the 2000 years of ceramic art in the Orient. Illustrated. E.J.V.

Exhibitions of Hittite and Scythian bronzes and of Han potteries. ALVAN C. EASTMAN. *Parnassus*, pp. 31–35 (May, 1930); *Art News*, p. 3 (May 10, 1930); *Design in Ind.*, p. 7 (1930).—Two illustrated articles on a current N. Y. exhibition. Among the Scythians were many masters in ancient metal work. Their designs used chiefly for costumes or harness show a singular gift in suggesting action and movement, spirited horses and leaping rams. Flat designs and low relief plaques express an evident appreciation of rhythmic line and balanced mass.

Excavations in Italy. THOMAS ASHBY. *Times Lit. Supp.*, **29**, 392 (1930).—Ac-

tivities (1) in and near Rome, (2) in N. Italy, (3) in S. Italy, and (4) in Sicily, are described. At Aquila a wall mosaic found is remarkable for the use in it of seashells and small rods of colored glass on a background of vivid blue. H.H.S.

Henry Chapman Mercer obituary. R. P. HOMMEL. *Notes and Queries*, **158**, 345–46 (1930).—Born in Doylestown, Pa., June 24, 1856, M. became curator of American a nd prehistoric archeology at the Univ. of Pa. Inspired by the handmade pottery of the Pennsylvania Germans, he invented, in 1899, a new method for making mural decorative tile, and in 1902, a process for making mosaics, thus starting the Moravian Pottery. His books include The Lenape Stone, Hill Caves of Yucatan, Antiquity of Man in Delaware Valley, Bible in Iron, and Ancient Carpenters' Tools. He died at his home, Fonthill, March 9, 1930. H.H.S.

BOOKS AND PAMPHLETS

Modifications in (American) Indian Culture through Inventions and Loans. ERLAND NORDENSKIÖLD. 256 pp. Oxford Univ. Press, 1930. Price 18s 6d. Reviewed in *Times Lit. Supp.*, **29**, 395 (1930).—Part VIII of N.'s series of comparative-ethnographical studies. The relation in S. America between independent invention and culture loans is discussed.

Additional Studies of the Arts, Crafts, and Customs of the Guiana Indians. WALTER E. ROTH. xvii + 110 pp. Supt. of Documents, Washington, D. C., 1930. Price $1.00. Has special reference to the Indians of Southern British Guiana. H.H.S.

Art in the Market Place. RICHARD F. BACH. Edited by Charles A. Beard. Longmans, Green & Co., N. Y., 1930. Price $3.00. *Toward Civilization; Design in Ind.*, p. 3 (1930).—The Director of Industrial Relations at the Metropolitan Museum shows how the machine has influenced production, buying and selling, and life in general. "In the machine age art can no longer remain impervious to the values of time and labor."

Commercial Art. C. E. WALLACE. McGraw-Hill Book Co., N. Y., 1930. Price $3.00. *Design in Ind.*, p. 8 (1930).—This text book is unique because it presents to the beginner correlated facts about drawing, design, lettering, and other fundamentals that are more often treated in separate volumes.

Color and Sales Promotion. JOHN ALCOTT. Metropolitan Life Insurance Co., N. Y., 1928. 12 pp. *Design in Ind.*, p. 4 (1930).—In an address before the Southern Mfrs. Sales Conference, Nov., 1928, A. analyzes good style and good design and shows how they may differ. He gives examples of how individual companies study style trends and predicts a national bureau to study style for the entire country.

Contemporary Detail in Common Brick. COMMON BRICK MANUFACTURERS ASSN. Reviewed in *Brick Clay Rec.*, **77** [3], 174 (1930).—The primary purpose of this portfolio is to make the architect brick conscious by presenting evidence of the detail effects that have been obtained with brick in this country and abroad. The portfolio contains 32 loose-leaf plates. Some extremely interesting details of American and European brickwork are shown in half-tone reproduction. An architect's detail drawing showing how the brick are laid to produce these attractive effects is included. E.J.V.

Small Homes of Architectural Distinction. ROBERT T. JONES. Harper & Bros. Reviewed in *Brick Clay Rec.*, **77** [3], 160 (1930).—A large number of designs of brick houses are illustrated in this book. Over 240 houses are shown by illustrations, floor plans, and descriptive text. The sizes are from three to six rooms and range in price from $3000 to $10,000. There is an index of several pages for different types of houses. A note on the construction material is given in connection with the descriptive text. Both solid brick walls and brick veneer are shown in many designs, and also a number of hollow-tile walls. E.J.V.

Les Animaux Vus par les Meilleurs Animaliers. ARMAND DAYOT. Moreau,

Paris, 1930. 5 vol's. Price $5.00 each. *Design in Ind.*, p. 7 (1930).—250 plates of designs which convert the animal kingdom into decorative motives for sculpture, bas-reliefs and illustrations, weather vanes, screens and book ends, and the myriad of objet d'art dear to the interior decorator.

Le Arti D'Oggi. ROBERTO PAPINI. Case Editrice D'Arte Bestetti e Tumminelli, Milano. Price $25.00. *Design in Ind.*, p. 5 (1930).—Present-day art is illustrated. The following subjects are discussed: architecture, interiors and furniture, metalwork, ceramics, laces, embroideries, fabrics, and wall papers. German jewels by Ernst Schmidt, Italian glass by Martinuzzi, Austrian architecture by Josef Hoffmann, French metal work by Brandt, etc., are described.

Modern Italians. YOI MARAINI. *Arch. Rev.*, pp. 101–105 (Feb., 1930); *Design in Ind.*, p. 5 (1930).—An article intended to show that Italy, the home for centuries of pure and applied art, does not lag in the movement that is urging the artists of Europe and America into designing furniture, ceramics, textiles, etc., suited to the modern house and to modern needs. Gio Ponti, architect-designer; Martinuzzi, sculptor; Gerardi, artistic iron worker, are a few of the designers referred to. See also preceding abstract. Price $0.75.

Cent Planches en Couleurs d'Art Mussulman. RAYMOND KOECHLIN AND GASTON MIGEON. Levy, Paris. Price $10.00. *Design in Ind.*, p. 5 (1930).—One hundred color plates of Mussulman art including ceramics, fabrics, tapestries, and rugs. While the introduction is in French, notes describing each of the full page plates are in English and German as well. Many suggestions for modern design are given.

Modern Decoration at the National Factory of Sèvres. (La Décoration Moderne a la Manufacture Nationale de Sèvres.) G. G. LECHEVALLIER-CHEVIGNARD. Massin, Paris. Price $15.00. *Design in Ind.*, p. 3 (1930).—During the past few years the national factory at Sèvres, formerly operated for state and official service only, has been making its ware for commerce. Twenty-four plates, many of them in color, showing design and decoration of Sèvres bowls, vases, and tableware are given.

Neues Porzellan. HERBERT HOFMANN. *Deut. Kunst und Dekoration*, pp. 133–37 (May, 1930); *Design in Ind.*, p. 4 (1930).—Beautifully photographed cups, saucers, bowls, vases, and ash trays show the strength and simplicity of porcelain made in the state pottery at Berlin. Price $0.75.

Heraldry for the Craftsman. F. G. SAYER. 120 pp. Blandford Press, Aylesbury, 1930. Price 7s 6d. Reviewed in *Times Lit. Supp.*, **29**, 395 (1930).—Heraldic work in metal, enamel, and wood, as applied to signs, plates, tablets, and gates, is described. A grammar of heraldry is included. H.H.S.

PATENTS

Design for bottle. MAGGY BESANÇON-DE WAGNER. U. S. 81,633, July 22, 1930; LOUIS HARRIS. U. S. 81,642, July 22, 1930; CALVIN R. WEBBER. U. S. 81,679, July 22, 1930.

Design for plate, etc. URASABURO TOMITA. U. S. 81,603 and 81,604, July 15, 1930.

Design for jar. ERNEST COHN. U. S. 81,627, July 22, 1930.

Design for counter. R. GUY COWAN. U. S. 81,684 to 81,687, July 29, 1930.

Design for cup, etc. GEORGE WESP. U. S. 81,728, July 29, 1930.

Design for sherbet. ALVAH C. PARKER. U. S. 81,738, Aug. 5, 1930.

Design for goblet. ALVAH C. PARKER. U. S. 81,739, Aug. 5, 1930.

Design for parfait. ALVAH C. PARKER. U. S. 81,740, Aug. 5, 1930.

Cement, Lime, and Plaster

Action of some salts, acids, and organic substances on cement and concrete. R. GRÜN. *Z. angew. Chem.*, **24**, 496–500 (1930); *Tonind.-Ztg.*, **54** [55], 921 (1930).—On the basis of investigations, G. concludes that the hypothesis "that water containing uncombined salts should not be used as diluting water for cement," must be revised. In fact, water containing uncombined salts is recommended for use as diluting water when these uncombined salts react with the uncombined lime of cement-forming salts favorable for the solidity and setting time (hydrochloric acid). On the other hand certain substances of organic nature like sugar and others, even in very small quantities, can retard and even prevent the process of setting. Of the salts which combine with lime to form difficultly soluble salts, oxalic acid is harmless for hardened cement. Strong phosphoric acid will injure hardened concrete with time. Diluted acids, on the other hand, have little effect and a good concrete is capable of resisting even phosphoric acid. M.V.K

Properties of cement bacillus and its origin by destruction of concrete by sulphate solutions. A. GUTTMANN AND F. GILLE. *Tonind.-Ztg.*, **54** [46], 759–62 (1930); *Pit and Quarry*, **20** [9], 74 (1930).—The authors review the researches of different investigators on the destructive effect of calcium sulpho-aluminates on concrete and describe their investigations, the results of which are as follows: (1) There is no doubt of the presence of the calcium sulpho-aluminate of Michaelis in synthetically prepared materials as well as in concrete destroyed by sulphate. (2) The calcium sulpho-aluminate of Michaelis is identical to the mineral, ettringite, as it was first determined by the authors, and it has the composition $3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}31H_2O$ (in the air-dried state or dried over sulphuric acid) according to the exact analyses of different investigators. Its optical properties, which were first determined correctly by the authors, distinguish it plainly from other known products of hydration. (3) Besides the cement bacillus, there exists a sulphate salt having little water $3CaO{\cdot}Al_2O_3{\cdot}CaSO_4{\cdot}12H_2O$ (Lerch, Ashton, and Bogue, *Ceram. Abs.*, **8** [7], 527 (1929)). It is stable only under quite definite conditions and is therefore found rarely in concrete samples destroyed by sulphate. The cement bacillus is formed under normal conditions from salt poor in sulphate, when this salt is liberated, and accordingly, is frequently found in concrete destroyed by sulphate. (4) With the action on concrete of stronger magnesium salt solutions as well as soluble carbonate, in the presence of sulphate, the calcium sulpho-aluminate of Michaelis is not permanent (Lerch, Ashton, and Bogue, *ibid.*); it is not permanent in solutions at temperatures higher than 40° (Kühl, Albert) and in acids. Otherwise it possesses a proportionately great stability. (5) The best protection against an extended formation of the cement bacillus in mortar and concrete is the use of a thick, fatty mixture which should be left to harden in the air, if possible. M.V.K.

Diatomite as a concrete admixture material. ELLIOTT S. HASTINGS. *Rock Prod.*, **33** [16], 55–59 (1930).—H. carried on an investigation of several diatomites and their use as admixtures in concrete and concluded that strength increases with the increase in diatomite content both at 7 and 28 days. R_2O_3 can be higher without decreasing cement strength in the presence of diatomite. Chemical analyses of cements and diatomites are given as well as particle-size analyses of the latter. Diatomite improves the workability apparently proportional to the surface factor of the added material and reduces efflorescence and kindred actions due to uncombined lime in concrete. Photomicrographs of various diatomites are shown. W.W.M.

Some errors in rapid methods of mix control. S. L. MEYERS. *Rock Prod.*, **33** [16], 60–61 (1930).—M. gives as the causes of discrepancies between lime content of raw mix and that of clinker, the presence of insoluble lime in the raw material and variable composition of the dust losses from the kiln stacks. He states that sintering the raw

material at 1000°C does not render all lime acid soluble and that fusion of the sample is necessary. Some materials are more easily carried by the stack gases than others, making the dust losses different in composition from the kiln feed. W.W.M.

Influence of mixing time on strength of cement. A. STEOPOE. *Rock Prod.*, **33** [15], 82 (1930); for abstract see *Ceram. Abs.*, **9** [8], 617 (1930). W.W.M.

Glass and porcelain cement. H. VON BERGE. *Kunststoffe*, **11**, 241 (1930); *Sprechsaal*, **63** [30], 567 (1930).—A classification of glass and porcelain cements approved by practice is given: cements for cementing glass with glass and porcelain with porcelain; cement for repairing cracks in glass bottles and porcelain objects; glass cement; glue fasteners for bottles; pastes for cementing glass pipes on wood; for fastening glass rods; for cementing metal plates on flat glass surfaces; for cementing metal plates and incandescent lamps in metallic sockets. The cement consists partly of organic materials as glue, Canada balsam, gelatine, colophonium, and partly of inorganic substances as gypsum, cement, kaolin, white lead, minium, in combination with drying oils. M.V.K.

Thermal expansion of cement and of cement with inert ingredients. S. UCHIDA. Sandai Higher Tech. School, *Bull.*, No. 7, pp. 425–78 (1928); abstracted in *Rev. mat. constr. trav. pub.*, No. 249, pp. 237–38 (1930).—Cement without admixture expands until the temperature reaches 100°C, then it contracts so that above 200° its length is less than at the beginning. From 300 to 400° the rate of contraction is less rapid, but above 400° the shrinkage is again considerable. A.J.M.

Magnesia and alumina. HEINRICH LUFTSCHITZ. *Tonind.-Ztg.*, **54** [54], 887–91 (1930).—H. reviews investigations made to substitute magnesia for lime in alumina cements and describes his own tests. The results of these investigations are given in tables. M.V.K.

Alumina cement in Germany. G. HAEGERMANN. *Rock Prod.*, **33** [16], 73 (1930); for abstract see *Ceram. Abs.*, **9** [8], 613 (1930). W.W.M.

Blast-furnace slag cements. A. O. PURDON. *Rev. mat. constr. trav. pub.*, No. 249, pp. 205–12 (1930).—Blast-furnace cement is capable of attaining high mechanical strength but hardens so slowly that it requires several months to become as hard as Portland cement. Hence, it cannot be used for work where early hardness is necessary. Blast-furnace cement is cheaper than other cements. The properties of blast-furnace cement, iron ore cement, and Portland cement are compared by means of graphs. A.J.M.

Theory of burning of cement clinker. HANS KÜHL. *Rev. mat. constr. trav. pub.*, No. 249, pp. 224–29 (1930). A.J.M.

Constitution of cements. N. P. COSTA. *Tonind.-Ztg.*, **54** [56], 937 (1930).—C. investigated the differences in the crystalline structure of the surfaces of different Portland cements and fused cements. The physical properties of the crystals change with the method of preparing cements and also depend on the quality of the cement; the velocity of cooling also has a certain influence. From the microscopical investigations of C., Portland cement clinker are solid solutions of isomorphous mixtures of calcium silicates and iron silicates with calcium aluminates. Fused cements represent a mixture of aluminates, silicates, and silico-aluminates in a glass of iron silicates. The main constituent of fused cement is $5CaO{\cdot}3Al_2O_3$ in an unstable form. The better properties of Portland cements which were prepared by the wet process, can be recognized on the surface by the great quantity and better structure of celite crystals and alite crystals. M.V.K.

True lime values on raw mix analysis. ROBERT R. KING. *Rock Prod.*, **33** [16], 60 (1930).—K. finds that in the complete cement analysis the lime value obtained is

always too high, sometimes 2 to 3%. This is due to the inability to wash out the alkali salts used in fusing the sample and K. recommends using only 0.1 to 0.2% of the alkali carbonates for fusing a half-gram sample of cement. W.W.M.

Factors in uniformity of cement. MARCEL BERNASCONI. *Rev. mat. constr. trav. pub.*, No. 246, pp. 81–88 (1930); *Pit and Quarry*, **20** [6], 77 (1930); *Tonind.-Ztg.*, **54** [52], 871 (1930).—Factors which are of the most importance to buyers of cement are (1) time of set and rapidity of hardening, (2) color, (3) apparent density, and as a corollary, fineness of grinding, and (4) quantity of mixing water required. To produce cement of constant quality two conditions are necessary and sufficient: (1) uniform chemical composition and fineness of grinding of the raw mix, and (2) uniformity of clinkering. The uniformity in the fineness of grinding, in turn, depends on (1) feeding the mills a material suitably prepared, (2) feed as regular as possible, (3) uniform degree of humidity in the material, and (4) uniform temperature of the material. The constant chemical composition of the raw mix likewise depends on (1) the nature of the raw materials, (2) care applied to proportioning and conditions under which the mixing of the raw materials is carried on, and (3) correcting the raw dry or wet mix after grinding. E.P.R.

Testing Portland cement. RICHARD AMMON. *Chem.-Tech. Rundschau*, **45**, 133–34 (1930).—According to the Soc. of German Portland Cement Mfrs., Portland cement is a hydraulic cement with not less than 1.7 parts by weight of CaO to 1 part by weight soluble $SiO_2 + Al_2O_3 + Fe_2O_3$. Special additions may amount to no more than 3%; at most, there may be present 5% MgO, 2.5% SO_3, and in heated cement no more than 4% loss by ignition. Testing methods are described, the properties determined being normal weight per unit volume, specific gravity, hardening rate, durability, fineness of grinding, and binding power. (*C.A.*)

Use of bauxite in Portland cement manufacture. J. DEFORGE. *Rev. mat. constr. trav. pub.*, No. 244, pp. 11–13; No. 245, pp. 64–67 (1930); *Rock Prod.*, **33** [14], 89 (1930); *Tonind.-Ztg.*, **54** [44], 743 (1930).—The article describes the wet preparation of Portland cement from limestone containing a great quantity of silicic acid, pure limestone, and bauxite in a revolving kiln. Bauxite is separated from the other materials, prepared, and after homogenization, is put into the mixing silos as a slip. M.V.K.

Crushing and preliminary grinding in Portland cement manufacture. A. C. DAVIS. *Cement and Cement Mfg.*, **3**, 813 (1930).—Crushing and grinding are necessary in nearly every stage of the manufacture of Portland cement. The raw material, fuel for the kiln, gypsum, and clinker all have to be reduced. Crushing and grinding processes are responsible for 80 to 85% of the total power required for cement works. This article describes the various types of crushing and grinding apparatus available for such purposes. W.L.

Mixed Portland cements. S. NAGAI. *Jour. Soc. Chem. Ind.* [Japan], **32** [7], 190B (1929); *Pit and Quarry*, **19** [11], 89 (1930).—"Neo-soliditit" cement is formed from 70 to 75% Portland cement clinker, 10 to 20% calcined granite, and 10 to 20% natural or artificial material containing soluble silicic acid. After 28 days combined curing, this product shows a compressive strength of 12,283 lb. per sq. in. and 838 lb. per sq. in. tensile strength. The three ingredients were mixed 3 to 5% gypsum added, and ground extremely fine. E.P.R.

Researches on Portland cements rich in iron oxide. I. S. NAGAI AND K. AKIYAMA. *Jour. Soc. Chem. Ind.* [Japan], **33** [2], 47–49B (1930); *Tonind.-Ztg.*, **54** [48], 802 (1930).—The authors undertook synthetic tests with different raw materials for the preparation of the so-called Kühl cement. The initial materials were two limestones and two Japanese pozzuolanas which contained about 20% Fe_2O_3. By heating up to 1320 to 1330°C, vitrified clinker was formed which contained 0.06% insoluble residue, 0.05%

free and 99.95% combined with lime. This clinker was ground with 2.5 to 3.5% gypsum in a porcelain mill. Tables give the chemical composition and the moduli of this cement as compared with the Kühl cement produced in Japanese plants. **II.** *Jour. Soc. Chem. Ind.* [Japan], **33** [3], 85–87B (1930); *Tonind.-Ztg.*, **54** [46], 771 (1930).—In preparing Portland cements rich in iron oxide, the authors used limestone and a kind of pozzuolana to which copper slags were added in one case, and, for the preparation of the so-called Kühl cement, a kind of loamy clay. The compositions contained 16 to 20% SiO_2, 6.27 to 10.07% Al_2O_3, 7.5 to 11% Fe_2O_3, and 59 to 65% CaO. The results obtained by heating the raw paste to temperatures above 900° are given in a table. The cements obtained by grinding vitrified clinker, fired between 1320°C and 1350°C, and by adding 2.5 to 3.5% gypsum were analyzed and their solidity tested. The results are tabulated. M.V.K.

Recent Japanese research in Portland cement. WILLIAM A. ERNST. *Rock Prod.*, **33** [15], 52–54 (1930); for abstract see *Ceram. Abs.*, **9** [8], 615 (1930). W.W.M.

New Japanese standards for Portland cement. K. BERGT. *Zement*, **18** [42], 1255 (1929); reviewed in *Pit and Quarry*, **19** [5], 102 (1930).—The fineness of division shall be such that not over 12% will remain on the 4900-mesh per sq. cm. sieve. A specific gravity of not less than 3.05 is required. The cement may contain not more than 2% SO_3 or 3% MgO. The loss on ignition may reach 4% and foreign additions are permitted to the extent of 3%. The initial set shall take place in not less than 1 hr., and setting should be complete in not more than 10 hrs., at a temperature of from 15 to 25°C. The 28-day strength shall be 355 lbs. per sq. in. (tensile) and 4260 lbs. per sq. in. (compressive). The weight of a sack of cement shall be 110 lbs. net, and of a barrel 374 lbs. net. E.P.R.

Manufacture of gypsum plasters. I. Extracts on operation. A. M. TURNER. *Rock Prod.*, **33** [16], 52–53 (1930).—T. discusses the occurrence of elemental sulphur in gypsum rock, the effect of rock-grinding methods on the quality of product and the position of rabble arms and thermometer in calcining kettles. He gives comparisons of gypsite and gypsum plasters, gives suggestions on emptying the hot pit and removal of foreign material from the molten gypsum, and discusses the setting of plaster. He states that gypsums from different deposits act differently. W.W.M.

Lime-gypsum plaster and process for producing. II. SAMUEL G. MCANALLY. *Rock Prod.*, **33** [15], 60–61 (1930).—When CaO is mixed with a hydrous material, such as raw or partially calcined gypsum, an exothermic reaction takes place at comparatively low temperatures. The hydrate becomes dehydrated and the lime becomes hydrated, while the heat evolved hastens the reaction. The reaction starts at the lowest temperature at which the hydrous material loses water, 140°F for gypsum. No external heat is required. For hard wall plaster, two parts gypsum and one part lime are mixed and heated, while agitating, to 180°F. The temperature continues to rise and when at a maximum the process is completed. For Part I see *Ceram. Abs.*, **9** [9], 712 (1930). W.W.M.

Lime and lime mortars. A. D. COWPER. Dept. Sci. and Ind. Research, Bldg. Research [London], *Special Rept.*, No. 9 (1927); *Pit and Quarry*, **19** [2], 116–17 (1929).—This report gives the various uses of lime, quicklime, and slaked or hydrated lime in building operations, and a practical classification of the different types of limes, and indicates for which use they are best adapted. C. reviews the development of the lime industry from early times to date. Lime burning is discussed, relating the effect of temperature and time treatment on limes of different compositions. Classification of limes is usually founded on the proportions of calcium oxide, magnesium oxide, and argillaceous material present. The most satisfactory classification is that of Vicat. The hydraulic quality of a lime may be determined by the value of the "hydraulic

index" which s expressed as % silica + % alumina/% lime. Weak hydraulic limes show an index from 0.1 to 0.2; good hydraulic limes will give from 0.2 to 0.4. The uses of lime are discussed. C. gives tentative specifications for quicklime, hydrated lime, hydraulic limes, lime putty, and lime mortar. W.L.

Colors for limes and cements, their properties and testing. C. R. PLATZMANN. *Rev. mat. constr. trav. pub.*, pp. 454–57 (1929); for abstract see *Ceram. Abs.*, **9** [4], 260 (1930). R.G.M.

Burning cement in dust form. SCHIRM. *Zement*, **8**, 15 (1929); *Pit and Quarry*, **19** [1], 112 (1929).—The process of clinkering cement in dust form, requiring no subsequent grinding, consists of allowing the powdered slip to fall through a shaft through which burning gases flow in the reverse direction. The height of the shaft must be between 150 and 300 ft., depending on the size of the slip particles, if a straight fall is used. E.P.R.

Lime in concrete. C. E. ELLSWORTH. *Nat. Lime Assn. Bull.; Rock Prod.*, **33** [15], 63 (1930).—Concrete should be impervious to water and hydrated lime is effective in producing impermeability. Results of strength and weather tests are given and a formula for arriving at the proper amount of lime to add. Addition of 8 to 10 lbs. hydrated lime per sack of cement seems to give best results. W.W.M.

Admixtures in concrete to prevent permeability. C. R. PLATZMANN. *Pit and Quarry*, **20** [9], 74 (1930); for abstract see *Ceram. Abs.*, **9** [9], 706 (1930). E.P.R.

Effect of zinc and zinc oxide on hardening of cements. ANON. *Rev. mat. constr. trav. pub.*, pp. 289–91 (Aug., 1929); *Pit and Quarry*, **19** [2], 117 (1929).—To study the effect of the zinc or one of the compounds, M. Pujol prepared a series of blast-furnace cement mortars and iron-Portland cement mortars with the addition of a variable quantity of zinc oxide, the proportion of ZnO being figured in percentage of the dry mortar. In general it was concluded that zinc oxide, even in traces, has a harmful effect on the initial set of cements with slag base; so far as the mixing of mortars on the zinc tables is concerned, it was concluded that the results were possibly due to action of free lime on the metallic zinc, but more probably to the presence of oxidized zinc at the surface. In a similar series of tests on other varieties of cements, M. Rengade found that ZnO had no perceptible effect on the setting time or strength of fused cement (ciment fondu). On Lafarge cement, however, with a normal initial set of 4 hr. 45 min., a final set of 11 hrs. 40 min., and 2-, 7-, and 28-day tensile strengths of 12.8, 28.8, and 30 kg./sq. cm., respectively, the addition of 1% ZnO (to weight of the cement) gave initial set of 21 hrs. 10 min., final of 42 hrs., and strengths of 0, 29.8, and 40. On Grapier cement there was an acceleration of the initial set but a retardation of the final set and a diminution of the strength. Rengade also noticed considerable variation in results on cements of the same type but from different plants. E.P.R.

Calgary gypsum plant open. ANON. *Can. Eng.*, **59** [3], 160 (1930).—The Calgary plant of Gypsum, Lime, and Alabastine Co., is producing lime, plaster, tile, and blocks. G.R.S.

Rotary kilns and waste-heat boilers. D. STEINER. *Tonind.-Ztg.*, **54** [52], 858–60 (1930).—S. discusses the question of using waste-heat boilers in rotary kilns and points out the difficulty of an exact estimation of the advantages and disadvantages of the installations of waste-heat boilers, because of the complexity and great number of other factors which must be taken into consideration, *i.e.*, (1) raw material and determination of content of lime, etc., fineness, water content of the slip, etc.; (2) kind of fuel and determination of its gas content, quantity of ashes, calorific value, humidity, fineness, and shape; (3) quantity of air maintained constant and temperature regulation for given kiln; (4) draft and temperature distribution; (5) position of sintering zone and regulation of revolutions. M.V.K.

Researches on rotary kiln in cement manufacture. I. Introduction outline. GEOFFREY MARTIN. *Rock Prod.*, **33** [16], 49–50 (1930).—This work includes the complete theory of the rotary cement kiln, based chiefly on thermodynamical calculation. The work was written after the collection of a mass of data from actual experiments and practice. A complete outline of the work is given by chapters. W.W.M.

Heat in cement clinker in a rotary kiln and air for combustion. ANON. *Rev. mat. constr. trav. pub.*, No. 249, pp. 220–24 (1930).—Recuperation of the heat in cement clinker is discussed in relation to preheating the air used for combustion. A.J.M.

Slurry filters and kiln heat losses. H. ENGEL. *Rock Prod.*, **33** [15], 83 (1930); for abstract see *Ceram. Abs.*, **9** [7], 505 (1930). W.W.M.

Influence of stack dust on cement quality dependent on method of feed. A. WEISSMANN. *Tonind.-Ztg.*, **54** [33], 563 (1930); *Rock Prod.*, **33** [15], 82 (1930); for abstract see *Ceram. Abs.*, **9** [8], 618 (1930). W.W.M.

Multistage process for firing Portland cement clinker. ROBERT D. PIKE. *Rev. mat. constr. trav. pub.*, No. 249, pp. 217–20 (1930); for abstract see *Ceram. Abs.*, **9** [7], 501 (1930). A.J.M.

Cement in 1928. B. W. BAGLEY. Bur. Mines, *Mineral Resources U.S.*, Part II, pp. 337–72 (1928).—In 1928 there were shipped from the mills 175,838,332 bbls. of Portland cement, valued at $275,972,945, an increase of 2% in quantity and a decrease of 1% in gross value. The average factory value per barrel in bulk in 1928 was $1.57, a decrease of 5¢ per barrel. Names of plants in all parts of the U.S. are given, where located, and trade name of cement. Statistics on consumption, imports, and exports are also given. R.A.H.

Le Société des Chaux et Ciments de Madagascar. ANON. *Zement*, **19**, 391 (1930); *Rock Prod.*, **33** [15], 83 (1930).—Plans are made to build the first cement plant in Madagascar, with an annual production of 36,000 T., using wet-process rotary kilns. W.W.M.

BOOKS

Structure of Mortars and Concrete. (Der Aufbau des Mörtels und des Betons.) OTTO GRAF. Julius Springer, Berlin, 1930. 150 pp. 160 illustrations. Reviewed in *Tonind.-Ztg.*, **54** [55], 919 (1930); for abstract see *Ceram. Abs.*, **9** [9], 713 (1930). M.V.K.

Some Writers on Lime and Cement from Cato to Present Time. CHARLES SPACKMAN. Reviewed in *Mining and Met.*, **11** [284], 22 (1930); for abstract see *Ceram. Abs.*, **9** [7], 507 (1930). E.J.V.

PATENTS

Cement manufacture. GEORGE A. WALTER. U. S. 1,770,958, July 22, 1930. In a process of making cement in a rotary kiln wherein a ring of molten cement-making material adheres to the kiln lining and obstructs the passage of the material through the kiln, the step of injecting into contact with the cement-making material in the kiln fuel having mixed therewith sodium chloride in amount approximately 2% of the cement-making materials employed, whereby when the latter are heated to a clinkering temperature in the kiln, the adhesion of molten masses of the material to the lining of the kiln is prevented.

Nozzle bank or valve for slurry. ANON. Ger. 488,568; *Tonind.-Ztg.*, **54** [14], 228 (1930); *Rock Prod.*, **33** [11], 91 (1930).—Nozzles of different diameters and equipped with valves regulate the feeding of slurry into revolving kilns. M.V.K.

Process for increasing shaft-kiln output. ANON. Ger. 489,833; *Tonind.-Ztg.*, **54** [17], 283 (1930); *Rock Prod.*, **33** [12], 90 (1930).—The kilns are used for firing lime, cement, dolomite, etc. The new process for increasing shaft-kiln output is described, in

which the cooling, prefiring, and firing zones are separated from one another. To obtain the highest possible combustion temperature only the exact quantity of air necessary for combustion is introduced into the firing zone. The prefiring zone receives a great amount of heat while the objects in the cooling zone are considerably cooled.

M.V.K.

Enamels

Use of Lindemann-Danielson cross-bending test machine. C. J. KINZIE AND G. A. PLUNKETT. *Jour. Amer. Ceram. Soc.*, **13** [9], 664–68 (1930); for abstract see *Ceram. Abs.*, **9** [3], 162 (1930).

Costs savings in continuous furnaces. C. A. DUTTON. *Jour. Amer. Ceram. Soc.*, **13** [9], 662–63 (1930); for abstract see *Ceram. Abs.*, **9** [3], 160 (1930).

Study of soluble salts in enamels. R. D. COOKE. *Jour. Amer. Ceram. Soc.*, **13** [9], 658–61 (1930); for abstract see *Ceram. Abs.*, **9** [3], 161 (1930).

Design for enamel smelting furnace. R. D. COOKE. *Jour. Amer. Ceram. Soc.*, **13** [9], 655–57 (1930); for abstract see *Ceram. Abs.*, **9** [3], 163 (1930).

Lead enamel vs. leadless. KARL FLECK. *Amer. Enameler*, **3** [5], 3–4 (1930); (translation of an article which appeared in *Emaillewaren-Industrie.*).—Leadless enamels are to be preferred because they do not endanger the health of the worker. In America, leadless enamels are rapidly taking the place of lead enamels for cast-iron enameling. In Germany, stove plants still are using lead-bearing enamels. It is to be hoped that the German stove factories will soon adopt leadless enamels. J.N.U., JR.

Raw lead ground enamels. ANON. *Emaillewaren-Ind.*, **7** [24], 185–86 (1930).—The following raw ground adheres well: A frit of 60 parts quartz with 40 parts borax to which clay and quartz powder are added together with additions of the required raw constituents which must be very carefully mixed, especially cobalt or nickel oxides. The oxides added must have the smallest possible grain size. All the salts soluble in water like borax, soda, and saltpeter, dissolve and diffuse completely and therefore a previous boiling is unnecessary. Borax and soda have a tendency to keep a certain amount of water and to crystallize. This process is avoided by quick hot drying. By this calcining of the salts, the enamel layer is exceptionally solid and adheres well.

M.V.K.

Colored enamel costs. ANON. *Better Enameling*, **1** [2], 10–13 (1930).—The selection of colored oxides and the milling and firing of colored enamels is discussed.

W.C.O.W.

Methods of measuring covering power of porcelain enamel. ANON. *Better Enameling*, **1** [4], 25–29 (1930). W.C.O.W.

Tests and control methods in manufacture of porcelain enamels. ANON. *Better Enameling*, **1** [4], 14–24 (1930). W.C.O.W.

Photomicroscopic studies. ANON. *Better Enameling*, **1** [3], 18–24 (1930).—The use of the photomicroscope in the study of the physical behavior of porcelain enamel is described. The following phases are discussed: (1) the effect of different furnace atmospheres on the bond which develops between metal and enamel, (2) influence of different metal bases on adherence, (3) effect of different enamel compositions on the bond which develops between metal and enamel, and (4) possible origin of some enamel defects. W.C.O.W.

Manufacturing porcelain enamels. ANON. *Better Enameling*, **1** [3], 12–15 (1930). W.C.O.W.

Porcelain enamel—what and how. ANON. *Better Enameling*, **1** [2], 10–13 (1930).—Composition and method of application of enamel. W.C.O.W.

Factors governing fuel efficiency of enameling furnaces. V. J. AZBE. *Fuels and*

Fur., **8** [2], 207–10 (1930).—The high-temperature working head (1800°F) of enameling furnaces necessitates a full understanding of the factors governing fuel efficiency if a furnace is to be designed and operated properly. It is the heat above 1800°F which counts and this decreases rapidly as excess air increases. Excess steam in oil burners may also cause large losses; this factor is discussed quantitatively. Gas analyses at a number of plants showed low carbon dioxide and high excess air to be common. A. describes the proper method for taking flue-gas samples. Curves showing the heat loss of enameling furnaces for various waste-gas temperatures are given. Sufficient combustion space and short flame combustion are important considerations. Open, semi-open, and closed-muffle furnaces are described and their fuel efficiencies compared. It is better to have a greater total surface and greater cubic content in a muffle since it can then be operated at a lower temperature. Reduction of draft frequently saves fuel. A.E.R.W.

Control of malleable furnace atmosphere improves operation and quality of product. W. F. GRAHAM. *Fuels and Fur.*, **7** [5], 705–706 (1929); (Abstract of paper, 1929, Meeting of American Foundrymen's Assn.).—By mixing flue gas with the inlet air, a uniform and easily controlled temperature was obtained and the oxygen content of the furnace reduced from 9 to 1% during the holding period. A.E.R.W.

Effect of furnace gases upon vitreous enamels. E. E. GEISINGER AND K. BERLINGHOF. *Fuels and Fur.*, **8** [3], 357–59 (1930); for abstract see *Ceram. Abs.*, **9** [3], 160 (1930). A.E.R.W.

Firing temperatures. ANON. *Amer. Enameler*, **3** [5], 7 (1930).—A brief review of some of the developments in enameling is given. Most of these developments were discovered by the large manufacturers of commercial enamels rather than by individuals who made their own enamels, as the latter could not afford the time or the money for the necessary laboratories and research. At present, commercial enamels have lower firing temperatures and are more efficient than others. Different enamels require different firing temperatures because the different ingredients put into them to bring about special results also affect the firing temperatures. The commercial manufacturers of enamels state a special firing temperature for each of their enamels. While this must be varied somewhat to meet local and special conditions, it should otherwise be adhered to very strictly. These instructions, coupled with present-day pyrometer equipment and the elimination of guess-work leave no excuses for over- or under-fired ware. J.N.U., JR.

Methods of molding castings for stoves, heating apparatus, and various builder's castings. H. MAGDELENAT. *Foundry Trade Jour.*, **43** [725], 24–27 (1930).—A description is given of the methods of molding a pedestal stove, certain cooking-range parts, a skylight frame, and a sink. H.W.A.

Factors affecting chilling properties of cast iron. A. L. NORBURY. *Foundry Trade Jour.*, **43** [726], 44–45 (1930).—Exact knowledge of the chilling properties of cast iron is most important. Gray-iron castings require an iron which will produce castings free from mottled or hard spots, but as close to the mottle as possible. Malleable castings require an iron which will produce castings free from spots of gray iron but as near it as possible. The chilling properties of a cast iron depend largely on its chemical analysis, particularly its silicon content. Results are given which illustrate the differences in chilling properties that may be obtained from irons of the same chemical analysis by melting conditions, while other results illustrate the effect of total carbon, silicon, phosphorus, manganese, and sulphur contents, and mold temperature on the chilling properties. H.W.A.

Blistering of enamel on cast iron. ANON. *Ceram. Ind.*, **15** [2], 181–84 (1930); see also *Ceram. Abs.*, **9** [8], 620 (1930). W.W.M.

Pickling of iron sheets. ANON. *Chem. News*, **141** [3657], 310 (1930).—The time of immersion in the acid varies from 15 to 30 min. HCl attacks the metal more or less rapidly and is suitable for hand operation, while H_2SO_4 acts mechanically in forcing the scale from the metal, and is used in mechanical pickling of modern plants. A description of the equipment for such plants is given. G.R.S.

Insuring good enamel castings. ANON. *Ceram. Ind.*, **15** [2], 161–63 (1930).—Some of the metallurgy of iron and steel is given in this paper, including the allowable impurities in cast iron which can be successfully enameled. Combined and uncombined carbon content is discussed and the effect of the presence of other impurities on it. Cupola practice in the production of cast iron is described and the views of two producers on the important factors in the production of good castings for enameling are presented. W.W.M.

High-quality cast iron in modern engineering practice. A. B. ENEREST. *Engineering*, **130** [3365], 56–58 (1930). A.A.

Advancement in iron and steel metallurgy during 1929. H. M. BOYLSTON. *Fuels and Fur.*, **8** [1], 23–36 (1930).—In a discussion of the progress made in ferrous metallurgy, B. describes the changes in dimensions and capacity of blast furnaces and the increase in size of open-hearth furnaces. In the operation of open-hearth furnaces, the use of dolomite charging machines has saved time and stock as well as making a better patch. Austrian and American magnesite were considered equally satisfactory. The use of silica brick in the upper courses of regenerator chambers, with fireclay brick below generally gives new life to the furnace and speeds up operation. A.E.R.W.

BOOKS AND BULLETIN

Textbook of Metallurgy. (Lehrbuch der Metallkunde.) FRANZ SAUERWALD. Julius Springer, Berlin, 1929. 462 pp. 29 Rm. Reviewed in *Mining and Met.*, **11** [284], 20 (1930).—Intended as a textbook for university students, this book aims to give a thorough grounding in the science of metals, the study of the properties, and the behavior of metals and alloys. The information covers that commonly given in courses on the strength of materials, testing of materials, theory of heterogeneous equilibrium, metallography, and technology, and is presented in a systematic, related way. Both ferrous and nonferrous metals are treated, and numerous references for further study are given. E.J.V.

Outline of Metallurgical Practice. CARL R. HAYWARD. The Library Press, Ltd., London. Price 30s net. Reviewed in *Engineering*, **129** [3362], 806 (1930). A.A.

White ground-coat enamels for sheet iron. ANON. *Better Enameling*, **1** [1], 15–19 (1930).—A reprint of a bulletin describing the results of an investigation of the Chicago Vitreous Enamel Products Co. in conjunction with one of the leading universities. W.C.O.W.

Glass

Dimensional changes caused in glass by heating cycles. A. Q. TOOL, D. B. LLOYD, AND G. E. MERRITT. *Jour. Amer. Ceram. Soc.*, **13** [9], 632–54 (1930).—In obtaining expansivity curves for a medium flint glass, samples of the glass were tested which had previously received one or another of several different heat treatments, and in these tests heating cycles were employed which made it possible to determine that the magnitude of the so-called "permanent" changes in length are caused either by the annealing or the "disannealing" which may result from the heat treatment imposed on the glass by the heating cycle employed. Annealing decreases the length and specific volume, while disannealing increases them. It is shown that these effects are related to certain

ice-point shifts observed in thermometers and to other effects sometimes observed in various types of glassware.

Mechanical properties of some rolled and polished glass. E. M. GUYER. *Jour. Amer. Ceram. Soc.*, **13** [9], 624–31 (1930).—A comparative study is made of the mechanical properties of several different kinds of rolled and polished glass. Young's modulus of elasticity and the transverse modulus of rupture are measured by the usual cross-bending method. Impact modulus of rupture is measured by means of a special form of pendulum which gives results that are free from the effects of cumulative chipping. Wind resistance is measured with a special form of hydraulic loading machine designed to give uniform pressure of the test plate against the supporting frame. The apparatus is described in detail and the results of the measurements are given in a series of graphs and tables.

Use of the polariscope in the glass industry. FRANK W. PRESTON. *Jour. Amer. Ceram. Soc.*, **13** [9], 595–623 (1930); for abstract see *Ceram. Abs.*, **9** [3], 166 (1930).

Chemical and physico-chemical reactions in grinding and polishing of glass. F. W. PRESTON. *Jour. Soc. Glass Tech.*, **14** [54], 127–33 (1930).—Large quantities of hydrogen gas are liberated during the grinding process due to the reaction between water and fine particles of iron ground from the grinding blocks. Analysis of the rouge cakes used showed besides rouge, silicates (glass), organic matter, water, felt fibers, and sodium sulphate. Indication of reaction between ferrous sulphate and glass is shown by the presence of sodium sulphate. Contamination of the felts with these materials causes a great deal of trouble in the new "continuous" systems of polishing glass. In the presence of ferrous sulphate gelatinous silica is precipitated together with iron hydroxides, both of which harden as the operation proceeds, while sodium sulphate is formed and if allowed to dry slowly appears as a white hairy growth of acicular crystals. G.R.S.

Investigation of the nature of rouge cake. W. M. HAMPTON. *Jour. Soc. Glass Tech.*, **14** [54], 133–37 (1930).—A thorough examination on rouge cake was made to test the correctness of the facts on which Preston founds his views of the changes which occur in polishing glass. Analyses were made of (1) the water extract from the rouge, (2) the residue insoluble in water but soluble in HCl, (3) the insoluble residue, and (4) loss on ignition. From these data the probable composition of rouge cake was found. The analyses and deductions indicate that the hypothesis put forward by Preston is justified. G.R.S.

Glass or not glass? F. W. PRESTON. *Glass Ind.*, **11** [8], 191 (1930).—The application of the name of glass to certain polymerized resins and other organic materials has again brought up the need for a satisfactory definition of the term. P. feels that a material is not technically a "glass" unless it contains an appreciable proportion of silica, and that in a more or less amorphous form. From the point of view of the industry, the essence of glassmaking seems to be the employment of high temperatures and the use of silicates, usually sand. The consensus of opinion of several well-known authorities and writers on glass was that it is undesirable to use the simple word glass to describe materials other than silicates. E.J.V.

Thermal endurance of glass. C. E. GOULD AND W. M. HAMPTON. *Jour. Soc. Glass Tech.*, **14** [54], 188–204 (1930).—Thermal endurance is defined as the property of withstanding sudden temperature changes without fracture. Chemical beakers of standard shape and size were selected as the type of article for use in this investigation. The method consists in heating a quantity of paraffin in the beaker to a predetermined temperature and plunging the beaker and contents into cold water. This is repeated at intervals of 5° until immersion causes fracture. The difference of temperature is recorded. Thickness of the beaker wall and the temperature drop necessary to cause fracture were found to be related. The empirical equation, $\theta\sqrt{2b} = B$, covers the curve obtained,

where θ = temperature drop, and $2b$ = thickness (max.) of the wall of the beaker at fracture. In practice the equation has only been applied to beakers, the maximum thickness of which lies between 0.9 and 1.9 mm. Objections to the test are (1) high temperatures often required cause a risk of fire, and (2) the hot paraffin coming in contact with cold water causes sputtering. Tests were made using rods instead of beakers, without success. Theoretical investigations were carried out on the rise of stress in infinite flat plates of various thicknesses, assuming that the surface of the plate was cooled on one side in accordance with Newton's law and on the other was maintained constant. Curves were computed from the resulting formulas and a relation between thickness and probable breaking temperature was found. Possible reasons for the discrepancy between this theoretical curve and the actual experimental results were advanced. An attempt was made to calculate the thermal endurance figure from the composition of the glass and a moderate degree of success was obtained. Tables are provided showing the relation between calculated and measured figures for thermal endurance. G.R.S.

Making quartz glass. ANON. *Sci. Amer.*, **142** [6], 474 (1930).—One of the first methods of manufacture of quartz glass was to fuse carefully selected quartz grains in a vacuum and then to press the mass at 1000 lbs. per sq. in. When cooled, the block was sliced into sections. In the present process, quartz sand is fused in a vacuum on flat graphite disks between thin graphite slabs in the form of a $7^1/_2$-in. square. A number of these trays are stacked in a form and placed in a high-temperature furnace. Fused nitrogen is admitted at a high pressure to compress the bubbles. G.R.S.

Changes of undercooled liquids in glasses. G. TAMMANN. *Nachr. Ges. Wissen. Göttingen; Math. Physik. Klasse*, p. 457 (1927).—For temperatures near the melting point the difference between the specific heats of the undercooled liquid and the crystals, *i.e.*, $c''p - c'p = Rp/Ts$. It was found that the specific heat of glasses increased considerably with rise of temperature. This was noted with silicate glasses, colophonium, and other mixtures, and also with chemical individuals. Two temperatures were specified for liquids which were undercooled, t_f, the lowest temperature at which a thread could be drawn, and t_v, the beginning of brittleness. Calculations were also made from the equation $\log\eta = -A + B.10^3/(T - T_\infty)$, η being the viscosity. The temperatures were found for which η is between 10^{13} and 10^{14}. An increase in expansion co-

Property	Salicin	Brucine	Piperine
$\eta = 10^{13}$–10^{14}	46–54	84–92	5–12
Increase of $c''p$	45–53	84–96	4–13
t_f	62	108	20
t_v	43–44	83–84	3–4

efficient was found between t_f and t_v. The changes which occur between t_f and t_v were given. The interior pressure increased greatly. No molecular change was probable. Undercooled liquids from their Eötvös constant have been shown to be associated. An expression was deduced for the increase of internal pressure during the abnormal interval. (*J.S.G.T.*)

Rate of crystal growth in technical soda-lime-silica glasses. IV. ADOLF DIETZEL. *Glass Ind.*, **11** [8], 185–90 (1930).—This installment takes up the dependence of the rate-of-growth curves on chemical composition; connection between rate of crystal growth and viscosity; isotherms of the maximum growth rates and isochrones of the minimum times for the formation of crystals of 10μ in length; practical rules for the composition of melts having the least possible tendency to devitrify; and si nificance of the extent of the devitrification range for manufacturing purposes. Illustrated. See also *Ceram. Abs.*, **9** [9], 726 (1930). E.J.V.

Density vs. composition of soda-silica glasses. ANON. Bur. Stand., *Tech. News*

Bull., No. 159, p. 70 (1930).—In addition to a study of the relations between composition and index of refraction of glasses, similar studies are being made with respect to density. Results indicate that the density of the soda-silica glasses in the range varying in composition from 55 to 80% silica and the remainder soda, can be computed from the expression: $D = 0.07977\ (86.5 - A)\ 0.42107 + 2.203$, in which A is the % of silica. Also from the expression: $D = 0.00301B - 2.988/B - 1 + 2.4756$, in which B is the % of soda present. R.A.H.

Determination of silica in phosphate rock. W. L. HILL AND K. D. JACOB. *Jour. Official Agric. Chemists*, **8** [1], 112–17.—Ordinary methods show low Si. The authors recommend the modified Berzelius method.

Decomposition of sodium sulphate. G. MARSCHAL. *Soc. chim. France*, **45** [4], 225 (1929); *Sprechsaal*, **63** [30], 564 (1930).—This article contains the results of investigations similar to those published (*Compt. rend.*, **188**, p. 259 (1929); *Sprechsaal*, **62**, p. 640 (1929)) with numerical data and curves. The curve shows that SiO_2 and Al_2O_3 greatly influence the disintegration of Na_2SO_4. For instance, after heating for four hours without additions the decomposition of Na_2SO_4 was not half as great as the disintegration with additions of SiO_2, heated for one hour. It is to be noticed, however, that at 1200° these reactions proceed at first very quickly, then slow down suddenly. The curve shows also that Al_2O_3 has a greater effect than SiO_2. M.V.K.

Striae in plate glass from the Fourcault process. OTTO STUMM. *Sprechsaal*, **63** [18], 326–28 (1930).—S. discusses the appearance of striae in plate glass and describes methods for finding them. The origin of these striae can be chemical, as the dissolving of clay in the liquid glass paste or from physical causes: (*a*) in the melting and purifying tubs, and (*b*) during the drawing of glass, as the continuous shaking of the drawing contrivance during the work. S. points out the necessity of laboratory researches to determine the physical nature of striae. Illustrated. M.V.K.

Laminated glass absorbs attention of three industries. J. F. WALSH. *Chem. Met. Eng.*, **37** [7], 418–21 (1930).—Growth of this industry has been rapid in the past five years. Three small companies, at that time, represented a total of less than $100,000; now there are 12 well-established companies representing an investment of $25,000,000 to $75,000,000. The total output was 300 to 500 pieces per day, whereas now it is 50,000 to 75,000. Many new uses and demands are being made for this material. In the dry process the cleaned glass is coated with an aqueous solution of glue, dried, and assembled with a sheet of pyroxylin-plastic between two glass sheets. The sandwich is placed in a rubber bag which is sealed and evacuated, then subjected to heat and pressure. The usual conditions are a treatment of 7 to 15 min. at 220 to 250°F under a pressure of 150 to 250 lbs. per sq. in. In the wet or semiwet process, the cleaned glass is coated with a resinous lacquer and dried. The pyroxylin plastic sheet is coated with a bonding solution and placed between the glass sheets. The sandwich formed is pressed and then dried. There is no conclusive evidence of the superiority of either method. A list of U. S. patents, to March, 1930, is given in a table. G.R.S.

"Spider threads" of glass. ANON. *Sci. Amer.*, **142** [4], 306 (1930).—A brief description is given of the apparatus used in drawing fine glass fibers for use as cross-hairs in telescopes. G.R.S.

Glass resists 15-ton pressure. ANON. *Sci. Amer.*, **142** [5], 393 (1930).—A tiny glass window in a pressure chamber where experiments were performed under a pressure of 30,000 atmospheres was not broken. G.R.S.

Volumetric determination of alkali metals in glass. N. A. TANANAEFF AND A. K. BABKO. *Ukraine Chem. Jour.*, **4**, 539–43 (1929); for abstract see *Ceram. Abs.*, **9** [1], 63 (1930). (*B.C.A.*)

Uses of minor alkali metals. ANON. *Can. Chem. Met.*, **14** [7], 34 (1930).—Some

studies of the minor, or rarer alkali metals, caesium, rubidium, and lithium, have been made. Most minerals contain at least a trace of caesium, rubidium, and lithium, but deposits rich enough to furnish large supplies are few. Several minerals, particularly lepidolite, are rich in lithium; but only one, pollucite, is high in caesium, and no definite rubidium minerals are known. Lepidolite is largely used in manufacturing opal glass, for which purpose it must be free from tourmaline and other possible coloring materials. E.J.V.

Duplate corporation develops new product. ANON. *Nat. Glass Budget*, **46** [12], 3 (1930).—Decorative duplate is an outgrowth of the nonshatter glass and involves the lamination of colored, instead of clear pyralin. The result is a nonshatterable glass suitable for furniture. The color, being sealed between the glass, is indestructible and impervious to moisture, rough handling, and dirt; the product will retain its original beauty indefinitely. The glass is reversible. E.P.R.

Influence of addition of small quantities of alkaline salts on ease of melting and on working properties of soda-lime silica glasses prepared from cullet. F. W. HODKIN, W. E. S. TURNER, AND F. WINKS. Glass Research Assn., *Bull.*, No. 12 (Feb., 1925); for abstract see *Ceram. Abs.*, **9** [7], 514 (1930).

Testing of "resistance-glass" ampoules. J. PRITCHARD. *Pharm. Jour.*, **124**, 539–41 (1930).—An 0.02% solution of phenol-red in 60% alcohol is diluted 20 times with freshly distilled water and boiled for 8 min. immediately before use. Of the resulting solution 0.3 cc. is sealed in a 0.5 cc. ampoule, which latter is then placed in a Koch's sterilizer for 1 hr. The color of the indicator when cold, is compared with a set of five standards ranging in p_H from below 6.8 to above 8.0, and the ampoule is thus assigned to one of five arbitrary classes. The heating and comparison are repeated on each of the next two days. A batch of ampoules is "good" if 90% of them after the first heating and 80% after the third have p_H 7.7 or less. Those of German origin fully conformed to this standard, but English-made ampoules did not, except a sample made from special hard borosilicate glass. The indicator does not change at all in ampoules of Pyrex glass. The method of testing recommended in the German Pharmacopœia (1926) gives results in agreement with P.'s method, provided the glass is powdered sufficiently to pass through a No. 10-sieve but remain on a No. 20-sieve. (*B.C.A.*)

Modern measurements of the viscosity of glass. R. LEDRUS. *Rev. belge ind. verrières*, **1**, 96–98 (1930).—L. discusses mathematically the definition of viscosity, the unit of viscosity, laws of flow in capillary tubes (law of Poiseuille), application of the law of Poiseuille to the experimental determination of viscosities, and the formula of Margule. A.J.M.

Disintegration of glass by means of compressed steam. C. HASSLER. *Chem.-Ztg.*, **54**, 366 (1930).—The inner surfaces and edges of Petri dishes which had been heated for 30 min. in steam at 5 atmospheres showed, on removal from the autoclave next day a deposit of ice-crystal-like structure. Only traces of condensed water could be detected in the dish. The deposit was distinctly alkaline. The outer surfaces remained unattacked. (*B.C.A.*)

Theory of the composition of glass. E. ZSCHIMMER. *Rev. belge ind. verrières*, **1**, 105 (1930).—Z. discusses briefly the chemical composition of glass. A.J.M.

Evolution and tendency of mechanical manufacture of hollow glassware. A. WENDLER. *Rev. belge ind. verrières*, **1**, 104–105 (1930).—Various new machines are discussed. A.J.M.

Devitrification of glass: (1) Relative stabilities of different glasses; (2) Time-temperature curves of visible devitrification; (3) Proposed classification of glasses. C. W. PARMELEE AND A. J. MONACK. *Rev. belge ind. verrières*, **1**, 89 (1930); for abstract see *Ceram Abs.*, **9** [7], 512 (1930). A.J.M.

Note on the use of feldspar in glass batches. T. W. TALWALKAR. *Jour. Indian Ceram. Soc.*, **2**, 57–62 (1930).—As there has been a consistent increase in the price of soda in recent years, the attention of the Indian glass manufacturers is drawn to the possi ility of using feldspar in glass as a main constituent, a practice that has recently become common in foreign countries. Its occurrence in India, its cost, value, and effect on glass is discussed. A.A.

Danner process of tube drawing. JAMES BAILEY. *Glass Ind.*, **11** [8], 182–84 (1930).—A detailed description of this process of tube and rod drawing is given. The formation of the tube is similar to the familiar hand process, in that a body of conditioned glass is worked into a thick, heavy cylinder which is drawn out into a small long tube, and to a great extent the factors involved are the same. The thickness and size of the glass on the mandrel, its temperature, the internal air pressure, and the speed of draw are all determining factors in the size of the resulting tubing. It has, however, the difference that it is a continuous process so that once the various factors are properly adjusted, the resulting tubing will continue to be formed of like diameter and wall thickness. Illustrated. E.J.V.

Insulated regenerators on glass tank effects 655% return on investment. ANON. *Ceram. Ind.*, **15** [2], 196 (1930).—The operation of the glass tank of the W. T. Rawleigh Co. is described. The side and end walls of the regenerators were insulated with three inches of Superex, resulting in a 26.5% reduction in fuel consumption. The life of the regenerator refractories has not been affected. Cost and savings data are tabulated in the paper. W.W.M.

Making distilling columns of Pyrex glass. ANON. *Ceram. Ind.*, **15** [2], 194 (1930).—The Corning Glass Works has made Pyrex glass columns to replace those with lead linings, which are short-lived where distillation and acid reaction are involved. W.W.M.

Calculating the glass areas of window openings. ELMER GYLLECK. *Arch. Forum*, **53** [1] (Part 2), 127 (1930).—Four tables are published which were compiled for the purpose of saving time in the drafting rooms of architects where the ordinances must be closely followed in regard to the ratio of glass area to floor space. When the use of these tables is known, much time can be saved in calculating glass sizes, areas, and the masonry openings. E.P.R.

Cost of excess air-producer gas-fired glass tanks. JOHN W. ROMIG. *Glass Ind.*, **11** [8], 179–81 (1930).—The effect of excess air and fuel losses attendant on excess air often arises in the operation of glass tanks, but as a rule action taken for its control is limited. Heat losses due to excess air are believed by some to be considerable. The loss due to the minimum percentage required for complete combustion may be termed as the minimum loss or the practical operating fuel-cost balance. Percentages over the minimum represent the loss that actually exists. Methods of obtaining the necessary data and the use thereof in determining the cost of the heat loss due to excess air are given in detail. See also *Ceram. Abs.*, **9** [9], 725 (1930). E.J.V.

Completely automatic glass machines. FRANK R. PESSERL. *Sprechsaal*, **63** [8], 138–40 (1930).—P. discusses different types of completely automatic glass machines used in U.S. and Europe. M.V.K.

High-temperature electric furnace used in making quartz window panes. ANON. *Fuels and Fur.*, **8** [1], 123–24 (1930).—A new process for producing fused silica in sheet form for windows which cuts the cost of manufacture to one-fifth of previous costs is described. In the present process, quartz crystal, crushed to $^1/_4$-inch mesh, is fused in a vacuum on flat graphite disks between thin graphite slabs. When the quartz is fused, nitrogen at a pressure of 150 lbs. per sq. in. is used to compress the bubbles. The plates, so made, are $7^1/_2$ in. square and $^1/_4$ in. thick. A.E.R.W.

Innovations in glassworking. O. SCHWARZBACH. *Diamant*, **51** [26], 504–505 (1929).—The glassworking industry has shown more intensive inventiveness than any other industry with the exception of the electrical. A short description of some of the various German patents in this field is given. These include a machine for the production of glass tubes and rods, developed by Johann Fickl (Ger. 463,387); another of the same type developed by Siemens (Ger. 466,049); and one by the Société du Verre Sili Chromé Paris (Ger. 465,521); a machine for making lenses developed by Franz Bartel and Johann Cornelius (Ger. 466,201); and one for making pressed ware developed by Josef Kraus (Ger. 464,058). E.J.V.

Early plate glass history. ANON. *Nat. Glass Budget*, **46** [14], 16 (1930).—It is probable that the first attempt to manufacture plate glass in this country was made in 1850 at Cheshire, Mass. Extensive deposits at Cheshire of exceedingly good silica sand no doubt determined the location of the works. In 1853, the second glass works was erected at Lenox Furnace, Mass. About 1919 and for two or three years previous, a company in Philadelphia held patents for making cryolite into a material called cryolite or hot cast porcelain, resembling white marble when worked, but having all the qualities of glass. This material was worked in the same way as glass. The next works built in the U.S. were at New Albany, Ind., and it was at that place that polished plate glass was first successfully and continuously manufactured. E.P.R.

Fall Brook Division, Corning Glass Works. ANON. *Glass Ind.*, **11** [8], 175–78 (1930).—A detailed description of this new plant, built and designed specifically for the manufacture of glass tubing and rods, undoubtedly the last word in efficiency and modern construction, is given. Equipment, power services, glassmelting tanks, and the Danner horizontal type tube-drawing machines are discussed. Illustrated. E.J.V.

Colored laminated glass. ANON. *Ceram. Ind.*, **15** [2], 159 (1930).—The Duplate Corp. has developed a colored glass made on the same principle as shatter-proof automobile glass, using colored pyralin, which makes variable designs at a reasonable price. W.W.M.

New apartments have glass-enclosed solariums. ANON. *Ceram. Ind.*, **15** [1], 63(1930).—The Majestic Apartments being erected in N. Y. City will have corner solariums enclosed in glass on two sides. W.W.M.

Gotham skyscraper makes first use of glass brick. ANON. *Ceram. Ind.*, **15** [1], 88 (1930).—The last four stories of the tower of the 40-story Barbizon-Plaza Hotel, in N. Y. City, are built of glass brick in a steel framework. The outside of the brick are cut to give a dazzling reflection of the sunlight which can be seen for a great distance. Various unique lighting effects can be obtained within the glass tower, some duplicating the texture of moonlight. W.W.M.

Tygart Valley Glass Co. plant. ANON. *Ceram. Ind.*, **15** [2], 164–66 (1930).—An illustrated description of the plant and production processes of the Tygart Valley Co. is presented; also the history of its development. W.W.M.

Safety glass production in England. ANON. *Ceram. Ind.*, **15** [1], 92 (1930).—Triplex Glass Co. achieves mechanically all the important manufacturing processes. The glass is cut, cleaned, coated with gelatin, and dried under careful temperature control in a tunnel drier; then sprayed with a special preparation and redried. Two sections of the coated glass and the sheet of transparent celluloid forming the core are assembled and fed into a machine which carries the three units under the liquid spreading device and then squeezes them together. Next the sandwiched glass and celluloid goes to a multiple press which presses a hundred of these at a time. These edges of the glass are sealed by gouging out the celluloid to a shallow depth and filling with a water-proof bitumen compound. The edges are polished and the trade-mark stamped on the glass, which is then cleaned and inspected for sale. W.W.M.

Old London glasshouses. I. Southwark. F. BUCKLEY. *Jour. Soc. Glass Tech.*, **14** [54], 137–49 (1930).—Descriptions of glasshouses are given. G.R.S.

European glass production. ANON. *Glass Ind.*, **11** [8], 190 (1930); abstracted from *Glastech. Gesellschaft.*—Production capacity in drawn glass in the leading glass-making countries of Europe per annum (in millions of sq. m.) is Belgium, 59.7; Germany, 22.2; Czechoslovakia, 19.5; France, 19.2; Russia, 15; Italy, 6.6; Great Britain, 4.2; all other countries, 13.8. E.J.V.

Belgian glass for photographic purposes. ANON. *Pottery Gaz.*, **55** [638], 1283 (1930).—The Belgian production of glass for photographic purposes has recently increased considerably, although the problem of mechanical production of very thin glass has not yet been satisfactorily solved. E.J.V.

Czechoslovakian glass industry. ANON. *Pottery Gaz.*, **55** [638], 1279 (1930).—The Czechoslovakian glass industry includes 140 factories, with 125 furnaces. Flat or window glass, as in Germany, is made mechanically only. Czechoslovakia makes about one-eighth of the world total of flat glass, with a production of about 20,000,000 sq. m. See also *Ceram. Abs.*, **9** [6], 483 (1930). E.J.V.

Crisis in the French glass industry. ANON. *Céram. Verrerie*, No. 815, pp. 258–59 (1930); *Pottery Gaz.*, **55**, 1153 (1930).—The causes of the crisis are discussed. A.J.M.

German mirror-glass industry. ANON. *Pottery Gaz.*, **55** [638], 1253 (1930); reprinted from *Deut. Bergwerks Z.*—Employment in the mirror-glass industry has become so much worse that, after mature consideration of the whole situation and in view of the enormous stocks, the works have decided to reduce operations immediately to three days a week. E.J.V.

Italian glass industry. ANON. *Pottery Gaz.*, **55** [638], 1279 (1930); abstracted from *Glashütte.*—The Italian glass industry is receiving attention from the State Export Institute in Rome. A wider buying market than at present is to be procured, especially in respect to artistic glassware. While optical and scientific glass plays but a small part in the industry, public institutions are urged to buy only Italian products. E.J.V.

Continental safety glass production. ANON. *Pottery Gaz.*, **55** [638], 1279 (1930).—The construction of a new big factory with three furnaces for the International Mechanical Glass Co., of Houden-Goegnies, is said to be making rapid progress. This concern has taken up the production of safety glass, in view of the local automobile industry. The Belgian unsplinterable glass industry is expected to undergo a large development soon. E.J.V.

New experimental glass plant in Russia. ANON. *Amer. Glass Rev.*, **49** [42], 16 (1930).—An experimental glass factory in Russia, work on which was started in 1929, for investigating the mechanical production of various forms of glass products, will be completed this year according to *Keramika i Steklo.* The cost of the new project is estimated at 400,000 R. E.P.R.

Résumé of a course in glassmaking. ANON. *Rev. belge ind. verrières*, **1**, 107–108 (1930).—A list of books on glass technology, an outline of the course, and the first chapter (definition, glassy state, classification, chemical compositions) are given. A.J.M.

BOOKS

Mechanical Working of Glass. (Maschinelle Glasverarbeitung). A. WENDLER. Akademische Verlagsgesellschaft, Leipzig, 1929. 250 pp. Price 24 Rm. Reviewed in *Rev. belge ind. verrières*, **1**, 115–16 (1930), for abstract see *Ceram. Abs.*, **9** [7] 521 (1930). A.J.M.

Belgian Review of the Glass Industries. (Revue Belge des Industries Verrières.) Boulevard Audent 6, Charleroi, Belgium. Reviewed in *Glass Ind.*, **11** [8], 178 (1930).—

Under this style and title a new periodical came into existence in March, 1930. It appears monthly. It is sponsored by a number of glass companies operating in Belgium, including Libbey-Owens, and the leading editorial of the first issue states that the reason for its appearance lies in the fact that, while Belgium has been for long a glass country of the first importance, its technical literature and trade organs have been of the poorest. The first three issues contain articles by Belgian engineers and technicians written specially for the *Revue*, and a number of translations of works of writers in English, such as C. J. Peddle and J. B. Krak. E.J.V.

Springer's Book for the Glass Industry. 27th yr., 1930. LUDVIG SPRINGER. Friedrich Otto Müller, Altenburg, 1930. 278 pp., 28 illustrations. 5 Rm. Reviewed in *Sprechsaal*, **63** [22], 419 (1930); also in *Rev. belge ind. verrières*, **1**, 116 (1930).—This book contains the newest works in the field of glass research, the results, and progress of the technique in 1929. It is divided into the following parts: (1) general composition and properties of glasses; (2) fusing materials; (3) technique of firing; (4) general preparation of glass; (5) special composition and preparation of different kinds of glass; (6) refining of glasses. Appendix: (1) present state of the technique in glass industry; (2) 25 years of the State school for the glass industry; (3) literature index. M.V.K.

Die Glasfabrikation. GUSTAV KEPPELER. Vol. I. 2nd ed. Glass Publications, London. 778 pp., 730 illustrations. Price 65/-post free.

Annual of the Ceramists and Glassworkers of France. (Annuaire des Céramistes et Verrières de France.) Compiled by J. Hogrel. 543 pp. Reviewed in *Glass Ind.*, **11** [8], 184 (1930); for abstract see *Ceram. Abs.*, **8** [12], 933 (1930). E.J.V.

PATENTS

Rolling plate glass. LAMBERT VON REIS. U. S. 1,770,443, July 15, 1930. A plate glass rolling machine, comprising a forming pass, and a teeming table composed of a plurality of closely spaced rollers, with means for driving the several rollers at peripheral speeds progressively increasing toward the forming pass.

Manufacture of silvered glass. LUITPOLD OFFENBACHER. U. S. 1,770,991, July 22, 1930. An apparatus for finishing silvered glass, comprising in combination with a continuous conveying device, a mechanical flushing device capable of covering the whole breadth and the two sides of the glass, a drying device using hot air under pressure for the flushed glass, a mechanical spraying device for applying shellac to the dried glass and a second drying device using hot air under pressure for drying the coating of shellac.

Feeding molten glass. KARL E. PEILER. U. S. 1,770,994, July 22, 1930. The combination with a traveling mold, of a guide for directing charges of molten glass into the mold, the guide mounted to travel with the mold, and means for periodically swinging the guide into and out of register with the mold.

Sheet-glass leer. KARL G. KUTCHKA. U. S. 1,771,180, July 22, 1930. In combination in a leer for annealing a glass sheet drawn continuously from a molten bath, a vertical leer casing, a series of partitions at spaced intervals one above the other dividing the casing into a plurality of compartments and each comprising a pair of horizontal plates each of which is hinged adjacent the center of the leer so that it can swing down to an inclined position, means for maintaining the plates yieldingly in horizontal position, doors carried by the side walls of a part of the compartments, plates in such last compartments projecting inwardly and upwardly from the side walls thereof below the doors, and of such width as to be engaged by the first plates when they swing down, and a series of pairs of rolls extending through the casing for drawing a glass sheet continuously upward therethrough, the swinging plates each having a flexible edge adapted to engage the sheet of glass when the plate is in horizontal position, and adapted to engage the periphery of one of the rolls when the plate is swung down to inclined position.

Making plate glass. FREDERICK GELSTHARP. U. S. 1,771,213, July 22, 1930. In combination, a glass tank containing a body of molten glass and open above a portion of the bath, a pair of horizontally driven sizing rolls above the portion of the bath, at least one of which has its periphery immersed in the body of glass, means for cooling the rolls so as to prevent the glass from sticking thereto, a bending roll located directly above one of the rolls, a glass-receiving bed or runway extending laterally from the side of the bending roll, a truck mounted for movement transversely of the line of movement of the glass on the runway, and a lifting device on the truck supporting the runway and rolls and adapted to raise and lower the runway and rolls and to transport them laterally.

Insulating body of spun glass. OSCAR GOSSLER. U. S. 1,771,216, July 22, 1930. An insulating body made up of a plurality of superimposed layers, each layer including threads of spun glass disposed in substantially parallelism, the threads of one layer being disposed at an angle to the threads of the adjacent layer, the respective layers having relative freedom of movement.

Transparent glass plate. HENRY B. HIGGINS. U. S. 1,771,378, July 22, 1930. As a new article of manufacture, a composite sheet consisting of a pair of opposing plates of glass, each having upon one side a natural finish, and having the other side ground and polished, and an interposed sheet of tough, transparent material, the natural finished sides of the glass plates facing inward and being attached to the tough, transparent sheet.

Glass-surfacing apparatus. ALBERT E. EVANS. U. S. 1,771,404, July 29, 1930. In sheet glass-surfacing apparatus, a plurality of trucks adapted to carry a series of sheets to be surfaced, racks carried by the trucks, pinions at the front and rear ends of the plurality of trucks engaging the racks, power means for driving the rear pinion and yielding connections between the pinions tending to rotate them in opposite directions, so that the trucks lying between the pinions are placed under compression.

Polishing plate glass. HALBERT K. HITCHCOCK. U. S. 1,771,408, July 29, 1930. Process of supplying a polishing mixture to the felts of a plurality of polishing machines arranged in series for a straight-away operation, which comprises mixing a body of water and polishing material, agitating the mixture, and withdrawing volumes of the mixture in excess of the amount required for polishing at predetermined intervals and supplying the volumes in a heavy flow to the separate machines to soften and wash away the coating of old or used rouge caked on the felts and then to re-establish a new coating on the felts from the mixture thus supplied.

Making composite glass. WILLIAM OWEN. U. S. 1,771,416, July 29, 1930. A process of making a composite glass plate of definite predetermined dimensions, which consists in attaching a pair of glass sheets to the opposite sides of a sheet of pyroxylin plastic by the application of heat and pressure, using sheets having over all dimensions greater than the predetermined dimensions, and then cutting strips off all of the edges of the plate thus formed to bring the plate to the predetermined dimensions.

Rounding the edges of sheets. WILLIAM OWEN. U. S. 1,771,417, July 29, 1930. In combination in an edge-rounding machine, a driven abrading belt having one flight extending in a substantially horizontal direction, a support beneath the flight, means for holding the sheets whose edges are to be rounded in upright positions transverse to the line of movement of the belt with their lower edges resting by gravity upon the flight, means for maintaining such lower edges against movement in the direction of travel of the flight, but free to rock, means engaging the upper portions of the sheets, and means for reciprocating the means longitudinally of the belt to rock the sheets back and forth about their lower edges.

Absorption glass. FREDERICK GELSTHARP. U. S. 1,771,435, July 29, 1930. A

clear glass having a blue tinge when first made with high ultra-violet ray absorbing properties containing cerium oxide, and formed by fusing a cerium compound of chemically pure quality in a reducing batch with one-fourth to one-half ounce of cobalt oxide in a batch approximating 1700 lbs.

Take-off device for glass-forming machines. HARRY B. LAWSON. U. S. 1,771,576, July 29, 1930. A take-off device comprising a stationary support having a horizontal and an inclined portion, a gripping mechanism, means for operating the gripping mechanism synchronously with the movement of a rotary glass-forming machine table whereby a finished article is removed from the table, means for inverting the gripping mechanism thereby depositing the finished article in inverted position on the horizontal portion of the support, and means for moving the deposited finished article on to the inclined portion of the support after the gripping mechanism has released the article and moved out of its way.

Transferring glassware. THOMAS F. LAMB. U. S. 1,771,641, July 29, 1930. Means for transferring glassware from a mold including a vertical column, a sleeve having a head loosely turning on the column, a second sleeve having a head loosely turning on the column and movable vertically thereon, interengaging cams on the heads, a rigid arm extending from the second-named sleeve, a lever connected at one end with the rigid arm and having its other end fulcrumed on the column, a pair of jaw arms connected with the other end of the lever and having their movements for opening and closing controlled by the raising and lowering of the rigid arm, means for swinging the frame, and stops for limiting the swinging movements thereof in opposite directions, the interengaging cams adapted to cause the raising of the rigid arm and permit the lowering thereof at the stops.

Glassworking tank. LEONARD D. SOUBIER. U. S. 1,771,864, July 29, 1930. (1) In combination, a stationary suction mold, a hood including heating means spaced horizontally from the mold, a tank to contain molten glass arranged beneath the hood and mold, means constantly supplying fresh glass to the tank, means for reciprocating the tank to periodically expose a portion of the glass surface to the atmosphere, means operating in timed relation with the tank-reciprocating means to elevate the tank and bring the glass into charge-gathering engagement with the mold, and means operable to vary the degree of elevation of the tank. (2) In combination, a reciprocable tank to contain molten glass from which charges are periodically gathered, heating means located above the glass, a stack adjacent the heating means, a damper for the stack, a cam carried by the tank, and means actuated by the cam to change the position of the damper to thereby vary draft conditions.

Glassware-annealing leer. ALBERT N. CRAMER. U. S. 1,771,876, July 29, 1930. In a glassware-annealing leer, an annealing chamber, a ware conveyer extending therethrough, a partition extending longitudinally and transversely of at least a portion of the chamber and spaced above the conveyer, a series of longitudinally spaced transverse rock shafts journaled in the side walls of the leer, rock arms interconnecting the shafts and partition, means to adjust the angular positions of the rock arms and thereby correspondingly change the elevation of the partition relative to the conveyer, interconnected rock arms secured to corresponding ends of the rock shafts outside of the leer, an adjusting device operatively connected to one of the last-named rock arms for imparting a rocking movement to all of the arms to thereby vary the spaced relation between the partition and conveyer, the adjusting device including a threaded rod connected at one end to one of the interconnected rock arms, and a worm and worm-gear mechanism for moving the rod lengthwise to rock the arms.

Glassworking tank. LEONARD D. SOUBIER. U. S. 1,771,904, July 29, 1930. (1) A dam for a glass container comprising a substantially U-shaped unit, and depending legs

formed at intervals on the unit. (2) The combination of a tank to contain molten glass, an extension thereon providing a channel through which glass flows from the tank, the forward portion of the channel providing a gathering area and a cut-off receiving area, means for gathering charges of glass at the gathering area and depositing cut-off portions of glass at the receiving area, a hood over the channel, a burner carried by the hood, and means for reciprocating the head lengthwise of the channel and periodically exposing the gathering area, the burner arranged to direct a flame against the cut-off receiving area when the hood is in its forward position and to direct the flame against the glass flowing along the channel before it reaches the gathering area when the hood is in its retracted position.

Blowing bulbs. CHARLES W. CRAIG. U. S. 1,771,954, July 29, 1930. In a bulb-blowing machine, the combination of a suction gathering head and a hollow blowing spindle adapted to receive a blank dropped from the head, the head comprising a mold having a lower opening greater in diameter than the upper end opening in the spindle and the spindle comprising means for clamping the blank over the end opening.

Forming sheet glass. JOHN L. DRAKE. U. S. 1,772,072, Aug. 5, 1930. In apparatus for forming sheet glass, a plurality of pairs of sheet-forming rolls, the rolls of the first pair tapering from their centers toward their opposite ends and the last pair of rolls being substantially cylindrical, and means for feeding a supply of molten glass to the first pair of rolls.

Forming colored glassware. T. DAVIDSON. Brit. 329,022, July 2, 1930. Colored glassware, such as bowls, vases, tile, trays, ornaments, etc., is made with variegated, cloud, or streak effects by mingling glasses of different colors or shades, and the finished articles are coated with a backing of colored paint or enamel. *E.g.*, a flower bowl may be made mixing purple or other dark glass with light amber glass. The surface may be coated with ordinary paint or cellulose compositions, or with vitreous or enamel color which is burned onto the glass.

Glass pressing. O. R. STEPHEN. Brit. 329,449, July 9, 1930. Relates to a press for making a glass plate which has sockets or holes inclined to its surfaces and is particularly intended for use as an anti-dazzle lens for motor-vehicle lamps. According to the invention, the sockets are formed in the plate by pegs which can be moved obliquely into, and withdrawn from the molding space.

Gathering glass. R. E. THRELFALL. Brit. 329,468, July 9, 1930. A refractory ring for floating on the surface of molten glass to isolate a gathering area is provided with means for increasing its buoyancy to ensure that it will float in glass of low specific gravity, such as borosilicate glass. The ring may be made hollow or it may be made with a core of asbestos rope, cardboard, or papier mâché. After being made and allowed to dry, the ring is fired, but slowly enough to ensure that any gases given off by the core shall pass safely through the walls of the ring.

Delivering molten glass. UNITED GLASS BOTTLE MANUFACTURERS, LTD., AND T. C. MOORSHEAD. Brit. 329,880, July 23, 1930. A device for feeding charges of molten glass comprises a hollow reciprocating member which, by its movement, is adapted to isolate completely a charge from a mass of glass, and means whereby the charge is subsequently expelled from the device by compressed air or other fluid. The charge, during its expulsion, is caused to rotate about its vertical axis to assist in retaining it in its desired form.

Ornamenting hollow glass. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 329,940, July 23, 1930. In apparatus for coloring hollow glass articles, such as electric lamp bulbs, by applying powdered color to the frosted inner surface, the color is drawn from a container by an air-blast and directed against the frosted surface, the excess material returning to the container. Compressed air is delivered to the container by a pipe the

end of which extends into the enlarged end of a nozzle. The delivery end of the nozzle extends into an opening in the container, from which a pipe leads to a distributing tube. The article to be colored is placed over the tube and is held against a resilient washer by a spring-pressed arm. The color is projected through vertical slots in the tube which may be rotated. The excess material returns to the chamber through a passage, the compressed air escaping through a fabric bag which retains the powder.

Blowing glass bulbs. GENERAL ELECTRIC CO., LTD. Brit. 329,941, July 23, 1930. Relates to a glassblowing machine of the kind in which a large number of individual blowing heads are provided, particularly for the continuous production of electric lamp bulbs. The invention consists in providing, on or adjacent to each mold, a device for marking each bulb while it is being made in order that the particular mold in which any bulb is made may be identified. The marking device may consist of a number of needles which are pressed against a glass blank and mark the soft glass. The impression made by the needles is usually smoothed out when the blank is rotated in the finishing mold, but is seen as a group of small dots on the completed bulb. In place of the needle, stippling devices may be used which are charged either with an easily fusible enamel or with an etching medium. In another construction, the marking device is secured to a slider which is carried by guides mounted on the rotating frame of the machine. The slider may be moved, to bring the marker into contact with the bulb, by a cam-operated pinion or by a pneumatically actuated piston.

Coloring glass. DEUTSCHE GASGLÜHLICHT-AUER-GES. Brit. 329,946, July 23, 1930. Glass is colored by adding a mixture of neodymium oxide and praseodymium oxide, the relative proportions of the oxides being between 4:3 and 3:5. The color of the glass varies from a light ruby color to grayish-blue and brown-green according to the position from which it is viewed.

Glass. HARRISON P. HOOD. Can. 300,790, June 3, 1930. A clear glass free from SiO_2 contains 20 to 35% of an alkaline earth, 15 to 30% of Al_2O_3, 40 to 60% B_2O_3, and not over 3% of alkali. (*C.A.*)

Safety glass. I. G. FARBENIND. A.-G. Fr. 678,320, July 11, 1929. The intermediate layer uniting the sheets of glass is composed of cellulose derivatives of simple or substituted fatty acids with more than 3 C atoms, *e.g.*, the laurate, butyrate-laurate, acetate-butyrate or butyrate-naphthenate, with or without softening agents. (*C.A.*)

Apparatus for making safety glass. LOUIS J. KOLB. Fr. 678,322, July 11, 1929. (*C.A.*)

Glass. LUIGI PUTHOD. Ger. 496,853, Feb. 13, 1927. A furnace heated by atomized liquid fuel is described. (*C.A.*)

Glass-wool fibers. FRITZ SCHLOTTERBECK. Ger. 495,875, June 5, 1928. A method of treating glass-wool and slag-wool fibers consists in subjecting the fiber to the action of finely divided alkali, such as atomized dilute $Ca(OH)_2$ or water-glass solution, or to the simultaneous action of alkali and H. (*C.A.*)

Glass. LUDWIG HOCHSTEIN. Ger. 495,941, April 11, 1926. Addn. to 480,753. A glass prepared according to the method of 480,753 (see *Ceram. Abs.*, 9 [1], 33 (1930)) contains SiO_2 85–90, B_2O_3 13–9, Al_2O_3 1–0.5, ZrO_2 1–0.5%, and no alkali. (*C.A.*)

Heavy Clay Products

Reënforced brickwork opens greater possibilities. SHIGEYUKI KANAMORI. *Brick Clay Rec.*, **77** [2], 96–100 (1930).—Reënforced brickwork is defined as a combination of brick and steel with mortar acting as a unit. The adhesive strength per unit area between brick and mortar is about $^3/_5$ to $^1/_2$ of that between mortar and steel, so to equalize the total adhesive power, the adhesive area of the mortar and brick should be enlarged

inversely proportionate to their unit adhesive power. As brick absorbs water and transmits a certain amount of heat the mortar surrounding the steel rod must protect it and experience shows that the thickness of the mortar must be not less than $^1/_8$ in. A special form of brick developed by K. for this type of work has a recess, the center of which lies at the position $^3/_8$ of its length and $^3/_4$ of its breadth measured from the surface. The nature of reënforced brickwork is like reënforced concrete. Illustrated. See following abstract. E.J.V.

Reënforced brickwork indorsed. WILLIAM SCHLAKE, L. B. LENT, AND R. S. TILDEN. *Brick Clay Rec.*, **77** [3], 149–50 (1930).—Comments by these three men on the article by Shigeyuki Kanamori on reënforced brickwork are reported. Schlake considers it a valuable contribution to the scant information now available on the subject, while Lent discusses the advantages of reënforced brickwork and shows that it is being introduced in this country. Tilden believes that this type of brickwork offers great possibilities for a new use of standard material for the brick industry of the country. E.J.V.

Reënforced brickwork takes the place of reënforced concrete tie beam. GEORGE E. MORRISON. *Brick Clay Rec.*, **77** [2], 100 (1930).—Because a reënforced concrete tie beam is unsightly used with a brick or tile wall, reënforced brickwork is being offered as a substitute. The reënforced brickwork consists of three courses of brick of any desired bond, with a layer of expanded metal laid in the mortar joint between the first and second courses of brick. The width of the expanded metal should be about 6 in. (not less than 4 in.) for an 8-inch brick or clay-tile wall, *i.e.*, 2 inches less than the wall thickness. The metal is laid in the center of the wall and is protected from rust by at least one inch of mortar joint which should be tooled. The gage of the metal will determine the width of the strip. E.J.V.

Composite beams of hollow tile and concrete tests. ANON. *Commercial Stand. Monthly*, **7** [1], 19 (1930).—The Bureau of Standards has been making tests to determine the value of hollow tile in assisting concrete to resist shearing and bending failures. The hollow tile used in the construction of the beams for the shear tests were selected to provide data for the determination of the effect on the shearing strength of the physical properties of the tile, their weight, and number of vertical interior webs. The bend tests were planned to give information on the effects of the weight, number of cells, and arrangement of the tile on the strength of the beams in bending. The results of the tests indicated that one row of tile was equivalent in resisting shear to a concrete rib of the same depth and having a width of from 1.6 to 2.4 inches. At loads considerably less than the maximum, the tile were more effective in increasing the resistance of the beams to bending deformations than at the higher loads. The relatively lower values for the higher loads are believed to be due, at least in part, to partial failure of the bond between the concrete and tile. The results of subsequent tests indicated that the method followed in the construction and aging of the beams was not favorable to the development of as strong a bond as would have been obtained with other methods. E.J.V.

Study of procedure for determining crushing strength of hollow brick. V. BODIN. *La Céramique*, **32** [490], 1–10 (1929).—The variety of dimensions and forms of hollow brick necessitated numerous tests before specifications for good quality brick could be drawn up. Twenty-one kinds of hollow brick, including five different manufactures were secured for test. These cannot be classified, even loosely, into less than eleven categories on the basis of their dimensions. For test purposes they are divided as follows: (1) brick whose thickness is less than half their width, (2) brick whose thickness is approximately half their length, and (3) brick whose thickness is approximately equal to their length. In all cases the brick are cut so as to obtain specimens whose width is equal to their length. When these were tested flat, a sufficient number were cemented

together to give a stack having approximately cubic shape. This procedure made the tests similar to those used for stone, mortars, concrete, etc., where cubic specimens were used. The results of tests, both flat and on edge, of twenty one varieties are reported in tables. The following conclusions are drawn: (1) Approximately the same values were secured in flat crushing tests when one specimen was used instead of a cubic pile. (2) Values 50% too low were obtained when the cement facing was omitted from brick whose surfaces were not plane. (3) Of forty values obtained, only seven were greater than 50 kg. per sq. cm., only five were greater than 60 kg. per sq. cm., and the maximum value was 71.1 kg. per sq. cm. Specifications requiring 50 kg. per sq. cm. therefore eliminated a large number of useful products. (4) The strength on edge was greater than the strength flat, particularly for thin brick. B. suggests further work to determine whether thinner-walled brick would not be as serviceable as the thick-walled brick that were tested. B. also recommends a standardization and reduction in the number of sizes of brick. A.E.R.W.

Standardizing masonry units and openings. W. D. RICHARDSON. *Clay-Worker*, **94** [1], 37 (1930).—Discussing the work on standardization of masonry opening sizes and masonry unit sizes, R. points out that the thickness of mortar joints must also be standardized. A discussion of the point is asked for. E.J.V.

Multi-color brick. ANON. *Brit. Clayworker*, **39** [459], 134–35 (1930).—There is much interest in the question of coloring of facing brick and tile. The day of the bright red facing brick is long since past. As to the production of deep reds, purples, browns, etc., on the surface of sand-faced or scored brick, the first essential is to ascertain the most satisfactory way of handling the firing of the ware. The color is dependent on the state of oxidation of the iron contained in the clay and on the type of sand used for molding. The real bloom that is so essential in the brick must be acquired in the firing. The firing of multi-colored brick cannot be obtained without higher temperatures and longer maintenance of heat than ordinary brick. If a full heat is obtained and with ample air supply during the "after firing," the brick, if the clay is suitable, will turn out purple or dark brown. The heavier colors, blackish brown or black can be produced in the later stages of firing. Rough and pitted surfaces can be obtained by means of breeze added to the clay. Other variations in color can be produced by the use of commercial iron oxide (deep purple tone), salt (silver-gray tone), manganese (chocolate-brown), and zinc (green and yellow) which are thrown on during full heat. R.A.H.

Lime and sand-lime brick manufacture. H. SAEGER AND E. CRAMER. *Tonind.-Ztg.*, **53** [99], 1732 (1929); *Rock Prod.*, **33** [13], 95–96 (1930).—Lime used for the manufacture of sand-lime brick must be thoroughly slaked to prevent expanding. Tests on brick containing a large quantity of silica and prepared with coarsely ground, incompletely slaked lime, showed cracks in the brick after hardening. Brick prepared with the same lime finely ground and sifted, and slaked by a steam pressure of 8 atmospheres, were very hard and without faults. M.V.K.

Cellular cement mortars. C. R. PLATZMANN. *Cement*, **2**, 263–69 (1929); for abstract see *Ceram. Abs.*, **9** [9], 736 (1930). (*C.A.*)

Formation of blisters in stoneware pipes. L. HARTL. *Tonind.-Ztg.*, **54** [54], 893–94 (1930).—H. discusses the phenomena of the appearance of blisters on stoneware pipes. They appear, suddenly disappear, and reappear again. As the blisters are most frequently formed several hours after pressing, H. concludes that they are caused by faulty methods used in this process. M.V.K.

Study of fluorescence. W. ANGUS MCINTYRE AND R. J. SCHAFFER. *Rock Prod.*, **33** [16], 61 (1930).—The authors found that analyses of salts at and just beneath the surfaces of stone and ceramic structures showed varied compositions but high SO_3 content. CaO, MgO, Na_2O, or especially K_2O is the usual chief basic constituent. Soluble salt

content of a ceramic body is not a guide to its liability to fluoresce for salts may be derived from external sources such as mortar and backing, soil, atmosphere, cleaners, and preservatives. Alkali clean rs tend to cause fluorescence, and cement mortars are more likely to cause it than are lime mortars. W.W.M.

Utilization of brick as a building material. DOUGLAS SMITH. *Brit. Clayworker*, **39** [459], 140–42 (1930).—S. states that though recent developments may for the moment claim a large share of the attention of other building materials, brick has not been superseded in its own sphere. The beauty and versatility in brickwork designs which may be developed are brought out and examples given. The modern trend in brickwork is discussed. R.A.H.

Brick pavements for modern traffic. JULIUS ADLER. *Brit. Clayworker*, **39** [459], 145–47 (1930).—Development of the brick pavement into its present form is a record of successive changes designed to produce a surface better adapted to the changing requirements of traffic and general use. A. discusses the cement-grout filler, the perfect pavement, the modern product, depth of paving brick, foundation, and asphalt joint filler. R.A.H.

Building industry. WALTER W. HOOPS. *Brick Clay Rec.*, **77** [3], 155–56 (1930).—H. presents an analysis of the building situation which every business whose income comes from construction should study. The building industry is a nonindustry, a "crazy-quilt of independent jobs." This is the cause of many recurrent difficulties. There is plenty of money that could be used for home building. Suggestions are given as to how this money may be made available for loans. E.J.V.

Brick sewers guard public welfare permanently. ANON. *Brick Clay Rec.*, **77** [2], 101–102 (1930).—The permanency of brick sewer construction is shown by records of certain old sewers in Detroit, Mich. Sewers 83 years old are still in service, while sewers of concrete construction have failed and the maintenance cost has been quite large for the latter type and practically negligible for the brick. Illustrated. E.J.V.

Brick, today and tomorrow. A. E. FOUNTAIN, JR. *Brick Clay Rec.*, **77** [3], 152–54 (1930).—Brick is the building material of yesterday and of today, but if precautions are not taken it will not be the building material of tomorrow. The same sort of operations in laying brick are being used as were in use in Biblical times. More innovations in brick must be made for it to hold its position as the leading building material in the future. All innovations which have been made have been successful, so it is hard to understand why more are not made. Competitive materials are entering into consideration in the building material field. Illustrated. E.J.V.

Revive colonial brickmaking. ANON. *Brick Clay Rec.*, **77** [3], 171 (1930).—Brickmaking on colonial standards has been revived in Wakefield, Va., to insure that the reproduction of the birthplace of George Washington will be as exact to the last detail as is possible. The brick are being made of native clay by hand so that they will duplicate in appearance the brick of the old Washington homestead, where the first President was born nearly 200 yrs. ago. E.J.V.

Early brickmaking and some old brick buildings in Virginia. ELLIS LOVEJOY AND H. B. HENDERSON. *Clay-Worker*, **94** [1], 19–23 (1930); see also *Ceram. Abs.*, **9** [3], 183 (1930). E.J.V.

$5000 for a brick house. ANON. *Brick Clay Rec.*, **77** [2], 103–104 (1930).—In an effort to prove the right of common brick and tile to compete with frame construction in modest-priced homes, a modern 19.6- by 26.6-foot two-story, five-room Colonial home of all-masonry construction was built at Bellevue, Ky., at a total cost, including 10% for the contractor, of $4570.90. An itemized list of material and labor costs is given. Illustrated. E.J.V.

Hancock Brick and Tile Co. ANON. *Clay-Worker*, **94** [1], 26–32 (1930).—The

largest producer of drain tile in Ohio is that of the Hancock Brick and Tile Co., with their main plant located at Findlay, Ohio. The daily average capacity of this plant is 150 T. of high-grade ware. The Childs brothers, owners and operators of this plant, have built up and modernized their plant so that it is most efficient and economical throughout. They have been able to make and install labor-saving equipment which has lowered costs. A detailed account of the equipment and arrangement of the plant is given. Illustrated. E.J.V.

Dutch road clinker. A. HIELSCHER. *Tonind.-Ztg.*, **54** [50], 823–27 (1930).—The clinker used for roads in Holland is of a high quality. There are two methods of preparation, the so-called "wet-mold" and the "dry-press" processes. 300 million clinker are made annually by the wet-mold process, and 6 millions by the dry-press method. A special kiln, the "Vlamoven" (overhead flames), is used, in which the clinker does not come in contact with the fuel. The kiln is described. M.V.K.

The Pyramids. K. DÜMMLER. *Tonind.-Ztg.*, **54** [54], 899 (1930).—It is an error to suppose that the Pyramids were made of fired brick, as fired brick appeared in Egypt only with the Romans. The Pyramids were built of loam blocks. These blocks, after shaping, were dried in the sun for several days only, and immediately used for the construction; no mortar was used. The outer covering of the Pyramids consists of the hardest natural blocks, which were polished. M.V.K.

Curtis Bros. new brick products. ANON. *Clay Prod. News*, **3** [8], 1 (1930).—Brick resembling marble in their veined finish and appearing antique can be obtained in any color to harmonize with hangings of any type. The brick are guaranteed to last indefinitely and to withstand any climatic test. W.C.O.W.

BOOKS AND BULLETIN

Brickwork and Its Construction. WALTER R. JAGGARD. Oxford Univ. Press. 330 pp., 193 illustrations. *Arch. & Bldg.*, **62** [6], 189–90 (1930).—The preface prepared by F. E. Drury is a brief comment on the book and the subject. Brick sizes and manufacture are covered in a brief first chapter. A chapter on cementing materials follows, to the improvement in which is largely due the revived interest in brickwork and the wider extension of its use. A chapter follows on the appearance of brickwork due to the method of bonding. Lintels and arches are discussed extensively. Decorative brickwork is illustrated by drawings of patterned brickwork, cornice designs, niches, gables, and chimney stacks. The subject of bonding of walls is covered by a half dozen chapters going extensively into the subject. Foundations for walls cover brickwork on concrete foundations. The chapter on damp in walls is a discussion of varying conditions. E.P.R.

Steel Skeleton. (Das Stahlskellett. Schallsichere Wände. Nazellose Platten.) FEIFEL. WEDEKIND UND CO., Stuttgart, 1930. 38 pp. Reviewed in *Tonind.-Ztg.*, **54** [56], 935 (1930).—Instead of searching for new building materials, F. suggests a new standardization of brick. Illustrations show the many diversified uses of the size selected by him including the combinations with steel framework structures. M.V.K.

Specifications for Brickwork and Other Essential Information. COMMON BRICK MANUFACTURERS ASSN. Reviewed in *Brick Clay Rec.*, **77** [3], 160 (1930).—In addition to the specifications, there are included illustrations of hollow-brick walls, a page of skintled brick effects, drawings of the bonds and joints, and drawings of parapet wall waterproofing and spandrel waterproofing. Also included is a handy tabulation showing materials and labor required for 1000 ft. of wall of various types. There are similar tables for footings, piers, and chimneys. E.J.V.

PATENTS

Building block or tile. ALFRED H. STAMM. U. S. 1,771,275, July 22, 1930. A

hollow rectangular building tile having part of its top mortar-receiving wall depressed centrally below the plane of its inner or under surface along a line substantially paralleling the side walls creating a groove in the top surface of the top wall and an extension within the inner space of the tile, the lower wall having a portion thereof at each side of the center longitudinal line thereof extended into the space of the tile toward the top wall creating a groove extending substantially centrally of the tile, that portion of the lower wall between the named portions beneath the resultant groove being pendent and terminating substantially in the plane of the lower or outer surface of the lower wall.

Brick. SIDNEY S. LANE. U. S. 1,771,302, July 22, 1930. A brick wall having a window opening, etc., the face of the opening being formed in part of special brick having a notch extending transversely across their exposed surface approximately midway between the ends, and in part of other brick superposed upon or underlying the special brick and having the joint between them equal in width to that of the notch and registering therewith, whereby the notches and joints together form a continuous vertical groove in the face.

Rack for clay products. HAROLD D. MCKENZIE. U. S. 1,771,414, July 29, 1930. A rack for handling material including a supporting bed, an upwardly extending projection pivotally mounted at one end of the bed for limiting the movement of the material thereon, mechanism for latching the upwardly extending projection in its upward position, and means for releasing the latching mechanism for permitting the projection to drop to lowered position for exposing and permitting access to the material lying adjacent thereto.

Brick-veneering machine. ENOS A. STEWART. U. S. 1,771,660, July 29, 1930. A brick-veneering apparatus including means for forming a clay column, a chamber through which the column is passed, the chamber adapted to contain veneering material, and means movable within the chamber for maintaining a uniform pressure upon the veneering material in the chamber.

Porous concrete. A. F. BERRY. Brit. 329,291, July 9, 1930. A cellular concrete is made by mixing a hard porous aggregate, such as fired clay, and cement which is subjected in the presence of water and a metal powder to the action of sodium thiosulphate or its equivalent and optionally also to a rubbing or grinding action. Stalloy may be used as the metal powder. Blocks, brick, slabs, etc., may be molded from the concrete and may have pieces of hard material such as granite or hard metal incorporated in their upper surfaces.

Making pipes of clay, etc. SABINE BROS., LTD., AND A. E. SABINE. Brit. 330,061, July 23, 1930. A machine for making pipes of clay, etc., has a feed worm below which a boss is provided carrying three or more knives or blades. The boss is secured to the worm shaft. A flange is provided on the outer periphery of the feed worm, preferably on the lower side.

Brick, etc. JOSEF STEINBICHLER. Austrian 117,592, Dec. 15, 1929. Lightweight brick, etc., containing occluded air are prepared by charging a mold with a suitable self-hardening composition, *e.g.*, a paste of $CaSO_4$, and coke slack, and forcing in fine streams of air at the bottom of the mold. (*C.A.*)

Refractories

Thermal expansion of spinel. ANON. *Refrac. Jour.*, **5** [58], 368 (1930).—Petrographic examinations of refractory material containing spinel showed (1) that it was composed of isotropic spinel grains with fine particles of glass and a crystalline birefringent material, probably clino-enstatite or forsterite. The particles of glass and silicate were

generally distributed along the boundaries of the spinel grains but sometimes also as inclusions within the spinel. Spinel comprised at least 90% of the material. (2) After heating to 1800°C, the spinel grains and the glass grains appeared considerably larger but fewer in number. The birefringent, crystalline material had practically disappeared. (3) After heating a second time to 1800°C, the spinel and glass grains appeared to be slightly larger. The material had a uniform rate of expansion from atmospheric temperature to the temperature at which contraction commenced. Although the maximum expansion, 1.19% occurred at approximately 1510°C, contraction commenced between 1300°C and 1400°C, and between 1510°C and 1800°C the material contracted, the rate increasing directly as the temperature. After heating twice to 1800°, the material showed little change in expansion, approximating to that at 1400°C in both cases. The material commenced to contract slowly at approximately 1400° and continued to do so until a temperature of approximately 1730°C was reached after which the rate increased rapidly. The average coefficient of expansion from 20 to 1400°C was found to be 8.6×10.6. No deformation was shown by the material. The material gained in weight after heating. At the end of the second run to 1800°C it had gained 1% in weight.

E.P.R.

Researches on spinels. ANON. *Gaz. Chim. Ital.*, **60** [5], 389–98 (1930).—The following compounds were examined with X-ray by the powder method: $CuAl_2O_4$; $MgAl_2O_4$; $MgFe_2O_4$; $ZnAl_2O_4$; $ZnFe_2O_4$; $MnFe_2O_4$. These compounds, with the exception of the last, were obtained by calcinating at about 800° a mixture of the metallic nitrates first dissolved in water, then dried; the $MnFe_2O_4$ is obtained by calcining at 800° the hydroxides precipitated with KOH from a solution of the metallic chlorides. The data obtained by a study of the compounds by X-ray are given in a table. All the compounds examined crystallized in the cubic system with a structure similar to the spinel type. M.V.K.

Studies of the effect of chlorine, sulphur dioxide, and carbon dioxide upon various refractories. STUART M. PHELPS. *Jour. Inst. Metals*, **41**, 672; for abstract see *Ceram. Abs.*, **6** [11], 524 (1927). (*C.A.*)

Refractory mixtures for maximum slag resistance. C. E. GRIGSBY. *Fuels and Fur.*, **7** [5], 743–44 (1929); for abstract see *Ceram. Abs.*, **8** [5], 340 (1929). A.E.R.W.

Properties of dry-pressed refractories resulting from variations in forming pressures. R. E. BIRCH. *Fuels and Fur.*, **8** [3], 370 (1930); for abstract see *Ceram. Abs.*, **9** [5], 353 (1930). A.E.R.W.

Resistance to scorification of refractory building materials. W. MIEHR, J. KRATZERT, AND P. KOCH. *Tonind.-Ztg.*, **54** [49], 810–12; [55], 907–10; [56], 928–29 (1930).—Investigations were made to explain the destructive action of slags on refractory materials. The latest researches of Salmang (See *Ceram. Abs.*, **9** [2], 110 (1930)) and Robitschek on scorification of refractories are discussed. These include the composition of slags, composition of refractory blocks, structure of blocks, firing temperature of blocks, temperature at which slags act, and duration of action of slags by the crucible process. Seven different refractory materials, whose compositions are given, and the composition and structure of ten slags with fusing points varying from 1100 to 1300° are described. Three sets of tests were made: (1) temperature 1400°, duration of action of slags $^1/_2$ hr. in a laboratory kiln heated by gas; (2) temperature Seger cone 14 = 1410°, 8 hrs. duration in an industrial tunnel kiln; (3) temperature Seger cone 17 = 1480° 12 hrs. duration in an industrial Mendheim kiln. The effects of the chemical composition of slags on the properties of blocks are represented by curves showing the marked influence of the block structure and porosity. Blocks rich in alumina (also magnesite, spinel, and chromite blocks) raise the fusing point of slag and are less stable. Grog blocks rich in silicic acid are more affected by basic slags. The results of the action

of slags on blocks are tabulated and show a certain relationship between the chemical composition, fusing point, and viscosity of slags, as being especially important factors in their total action. The 210 tests showed that the most important factors affecting the action of slags are (1) structure of blocks; (2) viscosity of slags; (3) composition of slags; proportion of the two valent basic oxides to the sesquioxides and especially the ratio of $CaO:Al_2O_3$; (4) temperature at which slags corrode and its duration; and (5) composition of the refractory blocks. The difficulty of obtaining the same results in industry as in the laboratory, due to the fact that many other factors come up under the actual working conditions which cannot be foreseen in the laboratory, is discussed. M.V.K.

Standardization of refractory materials. ANON. *Tonind.-Ztg.*, **54** [51], 846–48; [52], 861–63 (1930).—Several methods of testing refractory materials for standardization are discussed. These include the determination of (1) stability against action of solid and liquid substances at high temperatures; (2) stability against slag; (3) resistance against sudden temperature changes; and (4) post shrinkage and post swelling. M.V.K.

Thermal expansions of fused alumina, bauxite, and diaspore. ANON. *Brick Clay Rec.*, **77** [2], 95 (1930).—Data obtained in an investigation of the linear thermal expansion of samples of fused alumina (artificial corundum), bauxite containing approximately 80% alumina (water-free basis), and diaspore of the grade used in the manufacture of refractories from atmospheric temperature to 1800°C are presented. E.J.V.

Andalusite minerals in refractories. ANON. *Blast Fur. Steel Plant*, **18** [8], 1361–62 (1930).—Andalusite, sillimanite, and cyanite have the same composition but differ in physical characteristics. Although it is in the manufacture of spark plugs that the andalusite minerals have been used most widely, these materials have various other industrial utilities. They are employed in the production of laboratory articles, *e.g.*, crucibles, casseroles, evaporating dishes, etc. Mullite refractories are used in the glass industry. Recent tests indicate that in firing electrical porcelain, saggers containing cyanite have a much longer life than those made from ordinary mixtures. Mullite refractories may be made by fusing alumina and silica in an electric furnace, but at present they are made principally from the natural aluminium silicates. The three minerals, cyanite, andalusite, and sillimanite are converted by heat to mullite and silica or to mullite and a siliceous liquid, but they are not interchangeable. The lowest temperature at which the alteration takes place is different for each mineral, cyanite altering at the lowest temperature and sillimanite at the highest. Mullite refractories may be manufactured either in the electric furnace or in gas- or oil-fired kilns. The mining and location of various deposits of these minerals is described. Market possibilities of the various minerals are also discussed. E.J.V.

Crucibles for melting glazes. ANON. *Fuels and Fur.*, **8** [3], 382 (1930).—Batch formulas are given for crucibles which proved successful in melting glazes with B_2O_3 content as high as 30% and glazes with PbO content as high as 60%. The differences found between the batch compositions of the glazes and their final chemical analyses are reported. A.E.R.W.

Special refractories. NATIONAL PHYSICAL LABORATORY. *Dept. Sci. Ind. Research*, Rept. for Year 1929, pp. 254–55.—The supply of special refractory apparatus of a widely varied nature, in connection with the various researches in metallurgy and certain other departments of the Laboratory, has been continued during the past year, and in addition to the regular production of crucibles, special furnace parts, and pyrometric apparatus of special designs, considerable work has been devoted to the development of new materials and new technique in their application. The new extrusion machine to which reference has been made in previous reports has now been completed and installed in

the Department. The machine, which is actuated by a hydraulic ram, has been designed to have the maximum flexibility of operation in order to meet the varied requirements of the work. It can be adjusted to operate at any desired angle, so that the extruded product may, if necessary, be supported by an inclined plate-glass receiving plate, so adjusted to suit the coefficient of friction of the tube or rod that the latter will slide down the table without exerting any pulling or pushing action on the material emerging from the die. This method has proved most successful. The machine will also operate in a horizontal or vertical position and can readily be adapted for use as a press. The plunger, which is made of stainless steel to resist corrosive action, slides in an outer cylinder which is provided with an interchangeable lining of softer material. In this way wear is mainly confined to the outer sleeve, which may readily be replaced. Wear has been reduced to a minimum, however, by the use of a very small clearance between the plunger and sleeve, so that the machine is thus, to a large extent, "self cleaning." The range of tubing, etc., which can be produced has been considerably extended by this machine, and much more rapid manufacture is now possible. Special dies of large size are to be made, and it is hoped that the production of tubes of large diameter will be possible by this means. In connection with the work on the effect of gases in steel, a refractory crucible or container for use with the induction furnace was required which would withstand conditions for which the china-alumina crucibles at present used in induction furnace practice are not suitable. Resistance to high temperatures, rapid heating, and severe temperature gradients, and the power to withstand the corrosive action of fluxes of a wide variety of acidic or basic composition under oxidizing conditions, were required for this purpose. Crucibles and tubes made from specially treated chromite ores were found to be suitable and are now giving satisfactory service in this research. The work on the production of articles of pure alumina of increased mechanical strength by suitable grinding, grading, and acid treatment has been extended, and tubes, crucibles, and other apparatus are now being produced in this material which are comparable in strength with that of well-fired articles of china clay. This hard material has proved of great value in several high-temperature researches and in the development of new methods of pyrometric investigation. The production of small articles of pure alumina by the casting process has proved successful and this method has now been extended to the preparation of larger and more intricate shapes. The firing of these bodies has not proved difficult and the method is likely to be especially successful for the formation of apparatus in which a minimum wall thickness is required. It has been found that the presence of silica in the small tubes used for the insulation of thermocouple wires is liable to lead to serious contamination in certain cases, and there is a further possibility that errors may arise when the usual fireclay insulating tubes are employed owing to the generation of an electromotive force between the thermocouple wires and the refractory at high temperatures. Very fine-bore, pure alumina tubing of considerable strength has been produced successfully for this purpose and, for certain high-temperature measurements, is now being substituted for the fireclay type previously employed. Attention is also being directed to the possibility of producing a high-temperature refractory of an impervious nature for the protection of thermoelements and alloys from contamination by gases and metallic vapors. This problem is complicated by the necessity of avoiding the use of any siliceous material, which may become reduced and lead to serious contamination by silicon. Work on these types of special refractories is proceeding, in particular, on the possibility of producing a glazed surface on a highly shrunk alumina body.

P. B. sillimanite. WILHELM FITZ. *Glastech. Ber.*, **7** [12], 576–81 (1930); *Stahl Eisen*, **50** [17], 559 (1930).—The occurrence, mineralogical, chemical, and physical properties of sillimanite are discussed. A comparison with the properties of andalusite

and cyanite is made. Descriptions of the working methods in the sillimanite works of the European Koppers P. B. Sillimanite Co. Düsseldorf-Heerdt, and articles made of sillimanite are given. The application and durability of sillimanite in practice are discussed. Illustrated. E.J.V.

Physical structure of refractory materials. T. S. CURTIS. (Trans. by R. V. Widemann.) *La Céramique*, **32** [492], 41–43 (1929).—A super-refractory brick of remarkable constancy of volume, resistant to load at high temperatures and to strongly reducing conditions is obtained by using a grog having about 52% alumina and less than 5% RO, constituted of mullite and a glassy bond, bonding it with a clay of the same composition, and firing to cone 17. To obtain this result, the grog should be produced at cones 30 to 32 with alternate reduction and oxidation. For less resistant refractories, the addition to the grog of 10 to 20% of an inert mineral fiber gives good results which can be explained on an analogy with the use of tow in plaster molds. In vitreous products it is necessary to control with extreme care the crystallization and the proportions of the grains even to the finest of the nonplastic elements. The use of the same inert mineral fiber as in the fire brick has increased mechanical strength and rigidity as well as the resistance to sudden changes of temperature. A.E.R.W.

Development of modern refractories. H. E. WHITE. *Fuels and Fur.*, **8** [1], 107–10 (1930).—Ancient iron furnaces were lined with clay and backed with stone blocks. Mixtures of clay and charcoal were used for strength and freedom from spalling. The 18th to 20th Centuries saw the final development of the ordinary fireclay refractory. Later developments are machine methods, standardized shapes, better blending and mixing, and improved firing methods. The clay carbon mixtures finally evolved into the crucibles using Ceylon plumbago and Klingenberg clay. Crystalline alumina, silicon carbide, and mullite are modern refractory materials. A super-graphite crucible containing silicon carbide and other new additions has been developed. Madagascar graphite has prolonged crucible life. The induction furnace is creating a demand for crucibles. The use of graphitic refractories for permanent molds is being investigated. A.E.R.W.

Heat insulation. E. H. LEWIS. *Engineering*, **128**, 581–82 (1929).—Progress in the use of insulation is pointed out and some of the advantages cited. A.A.

Effect of grain size on clay products. CHRISTOPHER E. MOORE. *Brick Clay Rec.*, **77** [3], 157–60 (1930).—The importance of a correct texture in articles produced from clay can hardly be overestimated. Ways in which clay particles can be packed together are considered. The best working properties are found in a clay having sufficient fine material to form a continuous film around the large, nonplastic particles. Large particles in direct contact without a lubricating film make a clay "short." Liability to warping during drying is owed to the absence of the strengthening "key" action of larger particles. There are two ways to open up the texture with a close graded-material. The first and most usual is by the addition of a relatively small quantity of large grains. The second method consists in reducing the proportion of medium-sized grains in the aggregate and increasing the proportions of the existing large and small grains. The second method gives a stronger, more uniform mass, free from flaws and internal cracks. Vitrification, contraction, and decrease in porosity consists, in the early stages at least, mainly of the gradual rounding of angular grains under the influence of surface tension, and the uniting of these grains with one another. This action is rendered possible by the decreased internal cohesion of the grains consequent upon the rise in temperature. Improvement of mechanical strength of fire brick may often be effected by altering the texture so as to increase the proportion of the largest and the finest grades at the expense of the intermediate sizes. The most suitable load-carrying texture for high temperatures is one in which a close packing is obtained with just sufficient fines to give a

firm bond. An excess of fine materials is to be avoided as the movement of the larger particles over one another is facilitated by the greater thickness of the viscous film. The shape of the particles is of importance as rounded particles slide over one another too readily to give a strong structure. The greatest strength is obtained with a closely interwoven mass of splintery or needle-like crystals, and it is this structure which confers on sillimanite refractories their high load-carrying capacity. E.J.V.

Action of titanic acid on refractory materials. HANS HIRSCH. *Tonind.-Ztg.*, **54** [47], 773–76 (1930).—The best known titanium minerals are titanium dioxide, appearing as rutile, anatase, and brookite, titanium iron ores and ilmenite, perowskite, and titanite. Titanium dioxide is a refractory material. Investigations showed that objects with 99% of titanium dioxide and only traces of iron could be fused at Seger cone 35. Its behavior at fusion resembles that of quartz and shows a similar viscosity. Rutile in consequence of its iron oxide content has a lower fusing temperature. Additions of TiO_2 to raw materials used in the refractory industry have apparently no influence on their fusion. Investigations were carried on to find the proportion of TiO_2 in different clays and grogs, and showed an average content of 1 to 1.5% TiO_2. The results of further experiments are as follows: (1) A 2% addition of TiO_2 only slightly impairs refractoriness and softening under pressure. (2) A 10% addition lowers refractoriness about 3 Seger cones. In binding and sagger clays the action of TiO_2 is greater. The process of shrinkage is not much influenced in sagger and binding clays. (3) A 2% addition of TiO_2 does not influence shrinkage of kaolin, but a 10% addition greatly increases it. A change of color to ivory and yellow also takes place. (4) The influence of 1% titanium dioxide in combination with other fluxes, 2% iron oxide, 0.5% magnesium oxide, and 0.7% calcium oxide, was tested. The two latter together with titanium dioxide do not influence in general the softening under pressure and refractoriness. These tests showed that titanic acid in small quantities does not change materially the properties of refractory clays. M.V.K.

Alumina in refractory materials. DUNN. *Refrac. Jour.*, **5** [58], 388 (1930); see also *Ceram. Abs.*, **9** [8], 651 (1930). E.P.R.

Refractory mortars. PHILIPP. *Refrac. Jour.*, **5** [58], 388 (1930); for abstract see *Ceram. Abs.*, **9** [7], 536 (1930). E.P.R.

Graphite and its uses. A. SETON. *Chem. and Ind.*, **49** [24], 393–94 (1930).—Occurrence, uses, and analyses of graphite are given. G.R.S.

Changes in thermal expansion characteristics during the firing of a silica brick. J. A. SUGDEN AND J. W. COBB. *Blast Fur. Steel Plant*, **18** [8], 1355 (1930).—The authors discuss the question as to how far the behavior of a silica brick in use, particularly its reversible expansion, depends on the stage to which its firing during manufacture has been carried. Numerous experiments were made, and the results studied, especially by means of the expansion curves. The authors did not find it possible to calculate reliable figures for the mineralogical composition. See also *Ceram. Abs.*, **9** [5], 355 (1930). E.J.V.

Refractories and their uses. FRANK RUSSELL. Presented before the Institute of Metals (Sheffield section). *Refrac. Jour.*, **5** [58], 355–58 (1930).—Composition, characteristics, and uses are given for chrome brick, silica brick, sillimanite brick, silumina brick, bauxitic fireclay, dolomite brick, cements and pastes, and insulating brick. E.P.R.

Terms used in the refractories industry. II. ANON. *Refrac. Jour.*, **5** [57], 315; [58], 359 (1930).—Reducing atmosphere, oxidizing atmosphere, tunnel drier, weathering, consistency, dolomite, magnesite, ball clays, drying, and combined water are defined and briefly discussed. For Part I see *Ceram. Abs.*, **9** [7], 534 (1930). E.P.R.

Determination of refractoriness of clays by percentage of chemically-combined

water. N. P. CHIJEVSKY. *Jour. Inst. Metals*, **42**, 684; for abstract see *Ceram. Abs.*, **9** [6], 431 (1930). A.J.M.

Progress in boiler furnace refractories. W. J. REES. *Eng. Boiler House Rev.; Refrac. Jour.*, **5** [58], 379–82 (1930).—Durability of the brickwork has been increased by various methods of air and water cooling. The primary requisite in a fire brick is withstanding high temperatures, but there are several factors that affect the life of furnace walls and arches. The walls are exposed to abrupt changes in temperature, to the action of high velocity, hot, dust-laden gases, and to strains due both to actual superincumbent weight of brickwork and to pressure set up by thermal expansion. Refractory walls and arches may be subjected to three distinct types of "failure;" (1) wear from slag action, which may be accentuated by the presence of reducing gases in the hot, high velocity stream of ash-laden gases, (2) spalling, (3) volume instability which may lead to structural weakness. Definite progress has been made in the production of brick which offer a higher resistance to these causes of destruction. Coal ashes are variable in fluxing action on brickwork. With many coal ashes the greatest resistance to corrosion is given by the "high alumina" brick, but with acid ashes greater durability is likely from siliceous brick. Slag action may build up a thick coat on the wall, which may prevent the free movement of the fuel, or it may result in the formation of fluid slags which both erode and corrode the brickwork. With grates and high-gas velocities, as much as 20 or 25% of the coal ash may be carried to the walls, hence not only the chemical composition and texture of the brick, but also their general shape and finish are important. The "simulated service tests," developed mainly by American technologists, are of considerable service in evaluating boiler-furnace refractories. Progress has been made in the development of spalling tests, but the complexity of this phenomenon is such that it has not yet been found possible to specify a standard test. Decided progress has been made in the production of brick of "sillimanite" or "mullite" type which even under severe conditions of service show only negligible permanent volume changes. A new refractory which is highly resistant to slag attack is a mixture of diaspore and chromite. It is also free from the high-temperature shrinkage characteristic of diaspore brick. It does not have the spalling tendency of chrome brick, but retains the slag-resisting properties of chrome brick. E.P.R.

Development of preparation of tank blocks. HANS HIRSCH. *Tonind.-Ztg.*, **54** [49], 806–10; [50], 827–30; [51], 842–45 (1930).—Requirements for tank blocks are volume constancy, resistance to high temperatures and to action of constituents of frit and glass, resistance to stirring of liquid glass batch, and, in a certain degree, stability to temperature changes. A homogeneous, solid, thick structure, a limited grain size, and a solid binding of this grain are necessary for mechanical and chemical stability. It is not possible, however, to fulfill all of these requirements, the stability to temperature change being especially difficult to obtain. H. reviews different methods of preparing tank blocks and describes results obtained with tank blocks of different compositions in Europe and America. Illustrated. M.V.K.

Brick for water-cooled furnaces. ANON. *Brit. Clayworker*, **39** [459], 133–34 (1930).—The constant endeavor to increase the output of furnaces and secure greater ease of working has led to far more severe conditions on boiler refractories than were usual 10 to 15 years ago. There seems scarcely any limit to the amount of heat which may be liberated in a furnace. The fire brick and blocks used for water-cooled furnace walls should be precisely the same quality and should have the same general properties as those used for similar furnaces without the water-cooled walls. In all furnaces the durability of the refractory lining is the principal consideration and no good purpose is served by using brick of inferior material. The shape of the brick or blocks must fit the arrangement of the water tubes used. Usually the brick are grooved to fit the tubes

with reasonable accuracy. It is cheaper to have these grooves made when the brick are molded. The tubes should fit closely to the brick as a series of bad contacts between the brick and tubes may make the latter almost useless resulting in rapid disintegration of the refractory. R.A.H.

Checker brick in glass-tank application. R. M. KING. *Blast Fur. Steel Plant*, **18** [8], 1356–61 (1930); reprinted from *Brick Clay Rec.*; see also *Ceram. Abs.*, **9** [9], 743 (1930). E.J.V.

User's viewpoint on the electric furnace. F. A. MELMOTH. *Elec. World*, **96** [3], 128–30 (1930).—The future of electric steel melting is bound up in (1) cheap electric current and (2) the development of refractories. Advantages possessed by the electric furnace are outlined. When refractories are developed to the point that full use can be made of the heat potentiality of the electric arc, then the electric furnace will relegate the converter, the open hearth, and the crucible to history. G.R.S.

Modern coke oven and by-product recovery plant equipped for the manufacture of town gas. D. V. HOLLINGWORTH. *Gas Jour.*, **190** [3496], 432–35 (1930); for abstract see *Ceram Abs.*, **9** [8], 665 (1930). G.R.S.

Silica- and semisilica-walled ovens. E. C. DIXON. *Rock Prod.*, **33** [15], 59 (1930); for abstract see *Ceram. Abs.*, **9** [6], 437 (1930). W.W.M.

Refractory linings. MORRELL. *Oil and Gas Jour.*, pp. 110–13 (1930); *Refrac. Jour.*, **5** [58], 388 (1930).—M. deals with nonmetallic protective linings used against corrosion in the larger elements of refining equipment and particularly for cracking equipment. When more fully perfected the linings will contribute a factor of safety from their insulating effect in addition to preventing corrosion. E.P.R.

Use of refractory materials in pulverized coal-fired furnaces. M. POULLE. *La Céramique*, **32** [490], 11–13 (1929).—A large number of refractory shapes are being used in pulverized coal-fired furnaces. These have to meet particularly severe conditions. These conditions result from (1) high temperatures attained (1400 to 1500°C), (2) abrasive action of the powdered coal in the flames, (3) expansion caused by heating to high temperatures, and (4) fluxing action of the ash when operating above its fusion temperature. The use of high-priced special refractories did not eliminate the troubles. For this reason steps have been taken to ameliorate the conditions by changes in design and by arranging the burners, etc., to prevent impingement and the melting of the ash. The important changes in design include (1) use of expansion joints; (2) use of hollow walls made of hanging pieces, the outside part taking the structural load and the inside part consisting of special shapes hung on metal supports; air was circulated in the wall and sometimes water-cooled steel tubes supported the special shapes; and (3) introduction of a blast of air that chilled the ash and carried it toward the evacuation door. The new designs called for certain properties in refractories such as (1) accuracy of dimensions, (2) homogeneity of structure, (3) uniformity of brands as well as the usual requirements of strength, refractoriness, resistance to thermal shock, etc. A.E.R.W.

Refractory materials in boiler furnaces. J. DESMARETZ. *Chaleur ind.* [Special No.], pp. 173–75 (April, 1930). A.J.M.

Some important changes in heat exchangers. RAOUL BRONNER. *Chaleur ind.* [Special No.], pp. 235–37 (April, 1930). A.J.M.

Reducing corrosion of glass tank block. C. J. UHRMANN AND S. M. SLATER. *Fuels and Fur.*, **8** [3], 381–82 (1930); for abstract see *Ceram. Abs.*, **9** [3], 166 (1930). A.E.R.W.

Annealing pressed steel hubs. W. M. HEPBURN. *Fuels and Fur.*, **8** [3], 363–64 (1930).—A continuous, pusher type, gas-fired furnace of firebrick construction is described. A.E.R.W.

Firms merge with North American Refractories. ANON. *Pit and Quarry*, **20** [8], 93 (1930).—The North American Refractories Co. of Cleveland, O., has announced its acquisition of the U. S. Refractories Corp. of Mt. Union, Pa., and of the Savage Mountain Fire Brick Co. E.P.R.

France leading Europe in bauxite production. ANON. *Pit and Quarry*, **20** [9], 74 (1930); for abstract see *Ceram. Abs.*, **9** [8], 648 (1930). E.P.R.

BOOK AND PAMPHLET

Foundry Practice. R. H. PALMER. 4th ed. Chapman & Hall. *Refrac. Jour.*, **5** [58], 365 (1930).—This edition is written from the American point of view and discusses types and uses of molding sands, cupola linings, and other refractory materials. E.P.R.

Armstrong's High Temperature Insulation for Equipment in the Steel Industry. ARMSTRONG CORK AND INSULATION CO. *Blast Fur. Steel Plant*, **18** [8], 1345 (1930).—The pamphlet presents a detailed description of the properties of cork, and fully illustrates its many uses in the industrial field. The last page of the pamphlet presents a chart showing the B.t.u. loss through furnace walls. E.J.V.

PATENTS

Furnace setting and control. GEORGE P. CRYSLER. U. S. 1,770,463, July 15, 1930. A furnace comprising masonry walls and a boiler supported thereby, the walls forming a combustion chamber and an ash pit, each of the side walls of the furnace having a longitudinally extending trunk duct therein and a plurality of vertical ducts communicating with the trunk duct throughout its length, the side walls each having supplemental, horizontally disposed, vertically spaced longitudinal ducts therein arranged above the trunk duct throughout its length, the side walls each constructed to provide a plurality of horizontally disposed passages between the vertical ducts and the supplemental ducts and a lesser number of lateral openings between the supplemental ducts and the combustion chamber.

Furnace wall and baffle. DAVID S. JACOBUS. U. S. 1,770,928, July 22, 1930. A wall member adapted to be placed between fixed cylindrical surfaces, having one of its sides rounded to fit one of the surfaces and having its opposite sides rounded to fit another of the surfaces, and having two of its other sides parallel to each other and making angles other than right angles with its rounded sides and perpendicular to a common plane.

Checkerwork construction. CHARLES W. ANDREWS, JOHN PHILLIP GRILLI, HARRY L. WETHERBEE, AND CHARLES E. DOUGAN. U. S. 1,771,282, July 22, 1930. A checkerwork construction comprising a plurality of superposed layers of brick, the brick having passages formed therethrough and being placed to form passages therebetween, the brick in superposed layers being so placed that the passages through the brick in one layer are in registration with the passages between the brick in another layer, and continuous columns of filler brick placed in the passages to reduce the effective area thereof, the filler brick breaking joint vertically with the checkerbrick.

Checkerwork. HERMAN A. BRASSERT, ALBERT J. HULSE, AND CHARLES W. ANDREWS. U. S. 1,771,286, July 22, 1930. A checkerwork construction comprising a plurality of brick laid in superposed tiers, continuous vertically extending passageways through the brickwork, and separate means inserted in the passageways whereby the effective area of the passageways for the passage of gases is successively reduced.

Checkerbrick and checkerwork construction. ALBERT J. HULSE. U. S. 1,771,298,

July 22, 1930. A checkerbrick having a longitudinal opening extending therethrough, the opening having longitudinally extending portions extending into the brick, whereby filler brick may be located in the opening.

Flue structure for regenerative stoves. ALFRED C. NELSON. U. S. 1,771,306, July 22, 1930. The method of laying up flue structures having flues cross-shaped on a plane perpendicular to their longitudinal axes comprising spacing the brick so that each brick can expand into a cross-shaped flue opening.

Furnace wall. DAVID S. JACOBUS. U. S. 1,771,850, July 29, 1930. In a furnace wall, spaced holding members and a plurality of tile disposed between the members and forming a plurality of arches therebetween, each arch being substantially unrestrained from outward movement and having its soffit forming the inner side of the wall, flexible means disposed between the members and contacting with the back of the arches to retain the tile in position, and a casing wall spaced outwardly from the arches to form an air space between the arches and the casing wall.

Furnace wall. JAMES C. HOBBS. U. S. 1,772,350, Aug. 5, 1930. A furnace wall comprising a plurality of courses of refractory blocks, with at least one pair of tile in each course spaced apart, a bonding material in the space and only at one end thereof, whereby the pair of tile is free to expand toward each other at one face but not at the opposite face of the wall, and a thin layer of clay cement over the other end of the space.

Treating aluminium-oxide minerals. THOMAS AUSTIN MITCHELL. U.S. 1,772,359, Aug. 5, 1930. (1) The method of treating crude aluminium oxide comprising the steps of mixing the oxide with an alkaline-earth material, which is capable of reacting with aluminium oxide to form an aluminate, and with a chemical compound having a non-alkali base and a sulphate radical which is capable of reacting with the material to form an alkaline-earth metal sulphate, and calcining the same to form the aluminate and sulphate. (2) The method of treating crude aluminium oxide comprising the step of calcining the oxide in the presence of alkaline-earth metal carbonate and sulphuric acid, the added ingredients being used in such amounts that an aluminate is formed with substantially all of the alumina present and at least 10% of the calcine consists of alkaline-earth metal sulphate interspersed throughout the product.

Treating aluminium oxide. THOMAS AUSTIN MITCHELL. U. S. 1,772,360, Aug. 5, 1930. (1) Method of treating crude aluminium oxide comprising the steps of mixing the oxide with alkaline earth metal carbonate and a material bearing a sulphate of a metal selected from the group consisting of iron, aluminium, zinc, lead, chromium, cobalt, nickel, and manganese, the carbonate being present in an amount sufficient to form alkaline earth metal compounds with all of the other reactive ingredients, and thereafter calcining the mass to form alkaline earth aluminate, sulphate, and other compounds. (2) Method of treating crude aluminium oxide comprising the steps of mixing the oxide with aluminium sulphate and an alkaline earth metal carbonate, the amount of the latter being sufficient to react with all of the alumina and the sulphate radical present as well as with the reactive impurities, calcining the mixture to form alkaline earth metal aluminate and sulphate, washing the calcine with water to remove soluble compounds, leaching with an alkali metal carbonate solution to form a soluble aluminate and subsequently recovering an aluminium compound from the solution.

Refractories. L. MELLERSH-JACKSON. Brit. 329,803, July 16, 1930. Grog for use in the manufacture of refractories is prepared by compressing the initial materials under a pressure greater than 200 lb. per sq. in., firing and grinding. The finished refractories are dense and free from voids and resistant to corrosion by molten glass.

Apparatus for making quartz objects by blowing and rolling. SOCIÉTÉ QUARTZ & SILICE. Ger. 496,662, Nov. 4, 1926. (*C.A.*)

Terra Cotta

Improvement of clay by washing. L. RUDOLPH. *Tonind.-Ztg.*, **54** [51], 845–46 (1930).—R. discusses the necessity of washing clays in the preparation of heavy clay products and describes installations for this purpose. M.V.K.

Study of the consistencies of raw terra cotta glazes. L. D. FETTEROLF. *Jour. Amer. Ceram. Soc.*, **13** [9], 675–82 (1930); for abstract see *Ceram. Abs.*, **9** [3], 204 (1930).

Method of measuring strains between glazes and ceramic bodies. H. G. SCHURECHT AND G. R. POLE. Bur. Stand., *Jour. Research*, **5** [1], 97–103 (1930); *Ceram. Ind.*, **15** [2], 179–80 (1930); for abstract see *Ceram. Abs.*, **9** [7], 542 (1930). R.A.H.

Manufacture of stoneware. T. W. TALWALKAR. *Jour. Indian Ceram. Soc.*, **2**, 65–74 (1930).—Cost of raw materials and various items of manufacture are discussed. See also *Ceram. Abs.*, **9** [9], 752 (1930). A.A.

BOOKS AND BULLETINS

Buildings in France. Iron in the 19th Century. Reënforced concrete since 1900. (Bauen in Frankreich, Eisen, Eisenbeton.) SIGFRIED GIEDION. Klinkhardt and Biermann, Leipzig, 1928. Price $3.00. *Design in Ind.*, p. 3 (1930).—This review tells a story of change and progress, stressing the work of A. G. Perret, Tony Garnier, and Le Corbusier.

German Architecture of Today. (Deutsche Baukunst der Gegenwart.) WALTER MÜLLER-WULCKOW. Langewiesche, Leipzig. Price $4.50. Reviewed in *Design in Ind.*, p. 3 (1930).—Over 300 full-page photographs are given in three groups, factories and workshops, houses and apartments, and public buildings. Factories designed as early as 1900 by Gropius and Behrens appear ultra-modern in America, 1930.

L'Architecte. ANON. March, 1930. 6 plates, 8 pp. Reviewed in *Design in Ind.*, p. 3 (1930).—The use of molten basalt in architecture and plans for a new hospital in Saint Cloud, Minn., are given.

Machine and Architecture. STEPHEN F. VOORHEES AND RALPH T. WALKER. Edited by Charles A. Beard. Longman's Green & Co., N. Y., 1930, pp. 196–212. Price $3.00. *Toward Civilization;* reviewed in *Design in Ind.*, p. 3 (1930).—Architecture is an expression of living conditions. For today and tomorrow it must conform to a machine age. Significant points discussed are urbanization, specialization, food supply, vertical communities, the mass-production house, transportation, traffic, parking, and garaging of cars.

Heat Transmission. MARGARET FISHENDEN AND A. F. DUFTON. Dept. Sci. Ind. Research, Bldg. Research, *Special Rept.*, No. 11, 19 pp. (1929).—F. has been responsible for much valuable work concerning the heating of rooms. In the paper under review a résumé is given of the phenomena affecting heat transfer in particular application to buildings. The subject is discussed more from the fundamental aspects and points out that the application of an overall "air-to-air" coefficient of heat transfer "tends to obscure the true nature of heat transfer and may detract from the practical value of the available information;" for this coefficient varies widely with the conditions of experiment. These are pertinent remarks. D. gives useful data for the thermal resistances of various types of walls and building materials. This paper is the precursor of others dealing with experimental investigations on heat losses from buildings. The reports of such research will be welcome. (*Trans. Ceram. Soc.* [Eng.])

White Wares

Process of drying electrical porcelain. B. LAGRANGE. *Rev. mat. constr. trav. pub.*, No. 249, pp. 101–104B (1930).—The new Schilde drying process is described. The process is divided into 3 steps as follows: (1) the ware is heated in an atmosphere satu-

rated with water; (2) the ware is subjected to constant temperature and constant humidity; (3) the temperature is raised and the air passed into the chamber is drier. The three phases merge into each other. Curves are given to illustrate the process. A.J.M.

Casting ceramic bodies and different interesting applications of this method of fabrication. MARC LARCHEVEQUE. *La Céramique*, **32** [491], 21–26 (1929).—L. describes and gives examples with diagrams of (1) solid casting, (2) hollow casting, (3) combined solid and hollow casting, and (4) casting under pressure. Pressure is used to increase the maximum thickness which it is possible to obtain when casting under atmospheric pressure. The ware used as illustrations include dinner plates, mortars, soup-tureen covers, cooling coils, sanitary ware, and electric insulators. A.E.R.W.

Pebble mill linings. ROBERT TWELLS. *Jour. Amer. Ceram. Soc.*, **13** [9], 669–74 (1930); for abstract see *Ceram. Abs.*, **9** [3], 211 (1930).

Electric "safety valve." ANON. *Chem. Met. Eng.*, **37** [7], 442 (1930).—A new material developed by the Westinghouse Electric and Mfg. Co. has the property of being a good insulator below a certain applied voltage and a good conductor above that voltage. The material is of a ceramic nature and is permeated by millions of fine pores through which electric discharge takes place when the applied voltage reaches the critical value. See also *Ceram. Abs.*, **9** [4], 290 (1930). G.R.S.

Controlling processes in porcelain plant. FRANK H. RIDDLE AND HERBERT F. ROYAL. *Ceram. Ind.*, **15** [2], 174–77 (1930); for abstract see *Ceram. Abs.*, **9** [5], 362 (1930). W.W.M.

White ware manufacture in West Virginia. W. A. KOEHLER. *Mfrs. Rec.*, **98** [2], 54 (1930).—White ware is a term identifying a large group of ceramic products, the whiteness of which is due to the natural color of the raw materials. These raw materials in America consist essentially of clay, feldspar, and flint. W. Va., which ranks third among the states of the country, produces china and porcelain as exemplified by vitrified hotel china, electrical porcelain, high-tension insulators and sanitary ware; earthenware as exemplified by table ware, wall tile, and sanitary ware. China clay is an important ingredient in all white ware, about 340,000 T. of this kind of clay being annually imported into the U.S. from England. Being of a very poor plasticity, the china clay is supplemented in the process of manufacture by addition of ball clay, a more plastic material. As ball clay does not fire to the whiteness of china clay as little as possible is added. High-tension electrical insulators, though not representing a large volume of the white-ware industry in the state represents the highest type of white ware produced from the mechanical point of view. In manufacture of the high-tension insulators, vitrification is carried to its limit so that no pore spaces whatever are left in the ware. Samples of the insulators are subjected to rigid tests. The samples tested must show a puncture voltage of not less than 235,000 volts, a dry flash-over of 110,000 volts, and a wet flash-over of 55,000 volts. In addition, the samples must show an ultimate tensile strength of 11,000 lbs. and must withstand 10 to 30 one-minute cycles of changes from boiling water to ice-cold water. See also *Ceram. Abs.*, **9** [4], 292 (1930). E.P.R.

French porcelain industry. ANON. *Pottery Gaz.*, **55** [638], 1267 (1930); reprinted from *Céram. Verrerie.*—There has been a slow but persistent decline in the French exportation of artistic and luxurious furniture porcelain, from a total of 7650 T. in 1913 to no more than 6700 T. in 1929. French porcelain has to withstand the competition of other countries, particularly Czechoslovakia. Most of the export porcelain is made in Limoges, and is principally decorated, representing in value about two-thirds of the French porcelain exports. French faience is said to be increasing its position on the foreign markets, notwithstanding English, Dutch, German, and Czechoslovakian competition. French exports were 11,300 T. in 1913, and have risen progressively to 30,000

T. in 1929. The goods in question are mostly tile, decorated faience, and majolica, including toilet and sanitary goods. E.J.V.

Chinese porcelain industry. ANON. *Pottery Gaz.*, **55** [638], 1288 (1930).—Owing to unfavorable conditions, both as to production and sales, two of the most important and oldest porcelain factories in China, *i.e.*, the Chintechen and the Hsiaochow, situated in the province of Kiansi, have been obliged to shut down. A thorough study of the state of the industry is to be made to enable the investigators to suggest practical steps to prevent the collapse of the centuries-old industry. E.J.V.

BOOK

Porcelain Insulators and Porcelain for Insulators. (Porzellanisolatoren und Isolatorenporzellan.) STEN VELANDER. Svenska Bokhandelscentralen A.-B., Stockholm. 3.25 Rm. Reviewed in *Sprechsaal*, **63** [29], 552 (1930).—V. discusses the requirements for porcelain and the possibility of improving porcelain materials. Tests with porcelain and the results obtained are given. V. thinks that the chief error of porcelain insulators is the phenomenon of tiring, similar to that observed in metals. See also *Ceram. Abs.*, **9** [5], 362 (1930). M.V.K.

PATENTS

Self-insulated expulsion fuse and support. JOHN E. SUMPTER. U. S. 1,770,536, July 15, 1930. A self-insulated expulsion fuse and support including a porcelain insulating casing having a series of petticoat insulators spaced apart and extending from the outer surface thereof to provide a series of dry air gaps, an adjustable supporting member adapted to engage the casing between the ends thereof to provide a single supporting member for the fuse, and a fuse-explosion chamber and tube adapted to extend through the casing, the tube and explosion chamber being spaced from the casing in a manner to provide a dry air gap therebetween to protect the casing.

Lavatory and toilet seat. DAVID FRANKLIN YOUNGBLOOD. U. S. 1,771,945, July 29, 1930. A toilet fixture of the character described comprising a toilet seat; upstanding walls integral with the seat; and a wash basin arranged between the upstanding walls and above the seat.

Making decorated tile. VICTOR LEFEBURE. U. S. 1,772,257, Aug. 5, 1930. A process of manufacture of decorated tile, etc., of the kind consisting of two juxtaposed elements, and manufactured by pressing, with heating to a moderate temperature, a sheet consisting of a fibrous layer in which are incorporated reacting ingredients, *i.e.*, (1) silicates and (2) compounds which react with them to form a hard-resisting compound, and fillers, which process consists in producing on the surface of the tile a decorated effect by means of printing material adapted to finally form on the fibrous layer a hard resisting compound similar to that of the sheet.

Supporting pottery during firing. L. MELLERSH-JACKSON. Brit. 329,011, July 2, 1930. Complicated ceramic articles such as closets, which are molded and fired in one piece, are supported in the kiln so that the movement of the parts on shrinkage is facilitated, thereby avoiding strain in the finished article.

Equipment and Apparatus

Simple ruler for the interconversion of e.m.f. readings and p_H values in the electrometric measurement of hydrogen-ion concentration. J. GRANT. *Chem. and Ind.*, **49** [28], 302 (1930).—A diagram is given of the scales on the ruler with examples to illustrate their use in calculating the p_H value of the test solution from the electromotive force of the cell combination. G.R.S.

Fättinger torsion meter. ANON. *Engineering*, **128**, 542–43 (1929).—In the torsion

meter the indicator rotates with the shaft and dial brightly illuminated by a shaded electric lamp which moves with it. There is no difficulty in taking readings whether the shaft is running fast or slow. The torsion meter is illustrated and described. A.A.

Improved photoelectric cells. ANON. *Engineering*, **130** [3367], 108 (1930). A.A.

Ultra-violet light meter. H. C. RENTSCHLER. *Trans. Illum. Eng. Soc.*, **25**, 406–10 (1930).—A description with illustrations is given of a portable ultra-violet meter utilizing a glow relay tube and special U-photoelectric cell. See also *Ceram. Abs.*, **8** [11], 802 (1929). M.A.B.

Improved differential dilatometer. MAX HAAS AND DENZO UNO. *Engineering*, **128**, 424 (1929).—The alterations made on the underlying principle of the optical and differential dilatometer of Chevenard are described. They include (1) a construction which eliminates vibration, (2) a suitable type of furnace, (3) a different form of dilatometer tube, (4) a new dilatometer head, (5) the projection screen, and (6) standardization of test pieces. A.A.

Lateral extensometers. E. G. COKER. *Engineering*, **129** [3352], 465 (1930). A.A.

New adiabatic calorimeter. W. H. BARNES AND O. MAASS. *Can. Jour. Research*, **3**, 70 (1930).—A new adiabatic calorimeter equipped with a radiation thermal is described. W.L.

Constant-temperature preheater. S. T. BOWDEN. *Chem. and Ind.*, **49** [22], 257–58 (1930).—The apparatus was designed for more rapid and precise control of the temperature of water surrounding the observation vessel of refractometer and polarimeter. A Dewar flask is provided with a soft rubber stopper through which passes centrally a 300-watt electrical heater of the ordinary type. This is connected to the source of current through a variable resistor. Water is delivered into the Dewar flask directly from the tap through a tube ending in several orifices so that the issuing stream is swirled in several directions around the heater. A thick wad of thin copper gauze is fixed to the heater about half-way from the bottom of the flask to ensure equilibrium of the water temperature before it leaves the vessel. A small electrical thermoregulator to operate a relay in connection with the heater would control the temperature automatically. G.R.S.

Chemical composition of fusible cones from Nos. 022 to 10. ANON. *Corriere ceram.*, **11** [6], 257 (1930). M.V.K.

New pyrometer developed. ILLINOIS TESTING LABORATORIES, INC. *Gas Age-Rec.*, **66** [5], 190 (1930).—Among the features of this new pyrometer is the enclosed, quick-acting thermocouple which requires only 20 to 30 seconds for a reading. The thermocouple is easily replaced. The angle is adjustable, making it adaptable for crucible work or furnaces of various types. E.J.V.

Automatic control for industrial heating apparatus. G. C. PEARCE. *Fuels and Fur.*, **7** [5], 667–73 (1929).—P. describes the more common forms of automatic control apparatus including thermostatic control, pyrometers of the millivoltmeter and potentiometer types, automatic control panels, fusible links, and dual pyrometric control. Fusible links are made from an alloy whose melting point is slightly lower than the maximum safe temperature for the furnace. They are located near the work and connected in series with the control circuits, breaking the circuit in case of excess temperatures. In dual control, two couples are used, one near the heating element and the other on the work. The control is so set that the power is shut off by the couple which reaches its set maximum temperature first and does not go on again until both couples reach their set minimum. Dual control gives better results than single control. A.E.R.W.

Thermoelectric measuring instrument for surface temperatures. F. HOYER. *Chem.-Tech. Rundschau*, **45**, 291–93 (1930).—The pyrometer put out by Firma Kon-

stanz Vetter for measuring surface temperature is described and diagrammed, and is manipulated on the principle that a band of 2 different metals soldered in the middle and supported above by an elastic band produces a thermal current under the influence of heat, which is measured by an electric device with which the apparatus is provided. Suggestions for correct manipulation are given as well as the thermal results for distilled water, alcohol, ether, and xylene, as compared with thermometer measurements. (*C.A.*)

Alloys for use at high temperatures. I. W. ROSENHAIN AND C. H. M. JENKINS. *Engineering*, **129** [3361], 780–82 (1930); **II.** *Ibid*, **129** [3362], 811 (1930). A.A.

Industrial apparatus for gas analysis. J. HERMANN-MARITZ. *Chaleur ind.* [Special No.], pp. 223–27 (April, 1930).—Various types of apparatus are described. A.J.M.

Electrically-controlled steam-heated thermostat. H. W. CREMER AND W. B. HAWES. *Chem. and Ind.*, **49** [25], 511–12 (1930).—The thermostat was designed to operate over a wide range of temperatures and rate of flow. An accuracy of $^1/_{20}$°C in the thermostat was considered sufficient. Steam was furnished by a Spencer-Bonecourt gas-fired steam boiler of 280-lb. per hour evaporative capacity. An open tank of 100 gal. capacity was utilized for the thermostat. Nine tubes were installed sloping from end to end of the tank, and a regulator was used to alter the rate of steam-flow in them. A diagram is given of the wiring of the regulator. G.R.S.

Automatic gas-pressure controller. ANON. *Engineering*, **130** [3363], 841 (1930). A.A.

Flow instruments for high-pressure work. FOXBORO CO. *Gas Age-Rec.*, **66** [5], 189 (1930).—A new high-pressure recording flow meter and flow controller, built for operating pressures of 2500 lb. per sq. in., have been recently brought out. These are companions to the instruments for 5000-lb. pressure applications. Illustrated. E.J.V.

A zigzag drying installation. ANON. *Tonind.-Ztg.*, **54** [53], 879–80 (1930).—In the zigzag drying installation the movement of the air in the drying chambers is similar to that of the fire in a zigzag kiln. A ventilator supplies the fresh air and regulates the temperature and humidity of the drying air. M.V.K.

Drying installations and furnaces. W. E. GROUM-GRJIMAILO. *Rev. métal.*, **7**, 343–51 (1929); *Giorn. chim. ind. applicata*, **11** [12], 550–55 (1929).—The results obtained in plants which followed the suggestions of G. to profit by the laws of hydraulics for the study of the movement of gas in drying installations and industrial kilns are given. In installations hitherto adopted for obtaining the maximum heat in a restricted space, it was necessary that the hot air be forced over the charge several times by mechanical ventilators to saturate it with moisture before it left the chamber. With the system adopted by G., the same results are obtained by reheating the air in the lower part of the chamber and drawing the moist air into the upper part. The sudden cooling causes it to redescend into the lower part. A description of a single drying chamber using this method is given: Two steam pipes for heating and the inlet for fresh air and outlet for moist air are placed on the floor in such a way that the heated air and a part of the moist air is directed into the spaces on the side of the chamber and across the charge. When it reaches the floor a part is drawn away by an aspirator placed at the exit for moist air, the velocity of which is regulated on the basis of the hygrometer indications. The greater part of the air is reheated by the steam pipes so that the circulation is accomplished uninterruptedly. The temperature can easily be regulated by varying the size of the steam inlet. This principle has been applied with success to drying installations and kilns for different purposes. A tunnel kiln of 65 m. length rebuilt according to the design of G. yielded an increase of 50% in the production of faience with a corresponding reduction in the consumption of fuel. M.V.K.

Purchasing fans on specification. C. A. CARPENTER. *Power*, **72** [3], 92–94 (1930).—Some of the factors involved in fan problems are (1) operating performance on static pressure, maximum and minimum, (2) temperature, maximum and minimum, (3) speed, maximum and minimum, (4) corresponding static efficiency, (5) normal capacity, (6) the barometer, relative humidity; and (7) specific weights of gases. Fan specification should include a statement as to the type of fan wheel and give considerable attention to construction. After purchase and installation the fan should be tested from time to time using a standard fan test code. H.W.A.

New screening plant. ANON. *Pit and Quarry*, **19** [1], 115 (1930).—The Barber-Greene Co., Aurora, Ill., has developed a one-man excavating, loading, and screening plant, self-propelled, self-loading, and self-contained. E.P.R.

Improved grinding methods at the Diamond Portland Cement Co. ANON. *Rock Prod.*, **33** [15], 51 (1930).—Air separators are used in connection with raw grinding. Previously three Allis-Chalmers compeb mills, 7 by 21 ft., were used. It was found that the installation of a 14-ft. Sturtevant air separator in closed circuit with one mill increased its output from 1 to 18 to 22 to 23 T. per hour. Two mills connected in this way are now doing all the raw grinding. The product is 88 to 89% − 200-mesh and 97% − 100-mesh. W.W.M.

Raw grinding and slurry control. R. J. BINFORD. *West Penn Cement Safety News; Rock Prod.*, **33** [16], 41 (1930).—B. cites the advantages and disadvantages of tube mills and discusses the choice of grinding media with regard to size. The correct size of ball for the maximum size of particle passing the screen is $D = 3.18\,P^{53}$, where P is the diameter of the largest particle in inches and D is the diameter of the ball in inches. Slurry control includes (1) grinding to required fineness for efficient firing and desired quality; (2) maintaining as low moisture content as will permit easy and quick handling of slurry; (3) maintaining correct chemical balance of the compounds necessary in the finished cement. W.W.M.

New grinder introduced by Eagle Iron Works. ANON. *Pit and Quarry*, **19** [1], 116 (1929).—A new grinder, by Eagle Iron Works, has no screen plates or scrapers, hence the power requirement is low as well as the up-keep. E.P.R.

Single-roll crushing machine. ANON. *Engineering*, **129** [3362], 811 (1930). A.A.

Development in air classification. GEORGE ADAMS ROALFE. *Rock Prod.*, **33** [16], 47–48 (1930).—R. describes a specially designed apparatus using a rising air current for separating flake mica from mica schists and for many other applications in the rock products industries. He cites the possibility of the device being a substitute for screens in size classification. W.W.M.

Recent developments in the application of dry fine grinding with air classification. HOWARD G. WRIGHT. *Rock Prod.*, **33** [15], 57–59 (1930).—It is more important in grinding raw material for cement to eliminate coarse oversize than to produce superfines. Closed circuit by grinding will do this. Cement rock should be ground to about ½ in. in one mill and from ½ in. to 90% − 200-mesh in another mill, for most efficient operation. By use of reversed current, air classification (illustrated in the article), a product 95 to 100% −100-mesh can be produced without wasting power in the production of superfines, for as soon as the particles are fine enough they are blown from the mill. Examples have shown power consumption of 14 to 15 kw. hrs. per T. of 90% −200-mesh material. Mill lining and ball wear are small and dust loss is low. This system helps blend the raw material, is simpler, requires less floor space than most methods, and is economical. The principle of operation is described in detail and some fine points on air classification are given. W.W.M.

Filtered air for cement plants. ORVILLE ADAMS. *Rock Prod.*, **33** [15], 106–107 (1930).—A. says filtered air in cement plants prolongs the life of generators, motors, air

compressors, gas and Diesel engines, and other machines, and increases the efficiency and guards the health of the workers in the plant. W.W.M.

Improvement in air separator. ANON. *Rock Prod.*, **33** [15], 82 (1930); for abstract see *Ceram. Abs.*, **9** [9], 756 (1930). W.W.M.

Centrifugal dust collector. ANON. *Chem. Met. Eng.*, **37** [7], 440 (1930).—Western Precipitation Co., Los Angeles, Calif., has made a new high-efficiency dust collector known as the "Multiclone." It was developed for those conditions which are too small to justify the cost of a Cottrell precipitator. Efficiency will vary with the size and specific gravity of the particles, but it is claimed that the collector will catch all particles down to 6 microns and in some cases to 3 microns. G.R.S.

Centrifugal ore concentration. ANON. *Engineering*, **129** [3361], 775 (1930).—A discussion of "centrifugal concentration: its theory, mechanical development, and experimental results" is given. See also *Ceram. Abs.*, **9** [7], 556 (1930). A.A.

Portable, flexible conveyer of unusual design. ANON. *Ceram. Ind.*, **15** [1], 82 (1930).—A conveyer consisting of 2 spiral tubes which turn toward each other; the tubes are in 8-foot sections and a unit consists of 6 sections and a power head for turning them. The 50-foot conveyer may be set up horizontally or inclined and is adapted to convey bags, bundles, or bales. W.W.M.

Promal: new metal for chains. LINK-BELT CO. *Brick Clay Rec.*, **77** [2], 112–13 (1930); *Clay-Worker*, **94** [1], 38–39 (1930); *Mining and Met.*, **11** [284], 410 (1930); *Blast Fur. Steel Plant*, **18** [8], 1310 (1930).—A new method of processing malleable iron alters its physical characteristics so as to make it a distinctly new metal. Compared with malleable iron, Promal has an average yield point of 45,000 lbs. as against 36,000 lbs.; an average ultimate strength of 65,000 lbs. as against 54,000 lbs.; an average elongation of 14% as against 18%; and a Brinell hardness of 170 to 190 as against 110 to 130. Values for the same properties of mild cast steel, annealed, are 34,000 lbs.; 60,000 lbs.; 26%; and 120 to 140, respectively. Great toughness to resist extreme tension without permanent stretch; high strength in proportion to weight and size; and hardness that affords great resistance to abrasive wear gives chains made of Promal their surprising durability. E.J.V.

Handling brick in a steel mill. REFRACTORY ENGINEER. *Blast Fur. Steel Plant*, **18** [8], 1333–34 (1930).—A system by means of which refractory brick can be expeditiously and economically delivered from the car to the job is described. E.J.V.

Apparatus for cutting brick and similar products. P. RENAULT. *Rev. mat. constr. trav. pub.*, No. 249, pp. 106–109B (1930); see also *Ceram. Abs.*, **9** [9], 759 (1930). A.J.M.

Lubrication of equipment operating at elevated temperatures. H. SPURRIER. *Fuels and Fur.*, **8** [3], 333–34 (1930); for abstract see *Ceram. Abs.*, **9** [3], 204 (1930). A.E.R.W.

Spring-steel wire screen for long service. ANON. *Brick Clay Rec.*, **77** [3], 171 (1930).—Spring-steel woven wire screens of hard, resilient alloy perfected to withstand severe service on revolving, vibrating, shaking, and gravity screens are described. Spring-steel woven wire screens last several times as long as the same grades made of ordinary steel. Illustrated. E.J.V.

Electrical power in brick works. VII. ANON. *Brit. Clayworker*, **39** [459], 126–27 (1930).—The prorating of the power costs among the various departments of a brickworks is discussed. The distribution panel in each room is recommended and the use of a separate meter for each department. The use and advantages of the static condenser is described especially where induction motors are used. For Part VI see *Ceram. Abs.*, **9** [9], 759 (1930). R.A.H.

Operation of high-voltage apparatus. A. L. MÜLLER. *Electrotech. Z.*, **51**, 225–30

(1930).—A discussion is given of methods of operating high-voltage oil switches. The following methods may be adopted: ordinary solenoid, a magnet giving a circular motion, electric motor, or compressed-air motors giving reciprocating or rotary motion. Curves are given showing the operating characteristics of the various methods. M.A.B.

Long-distance transmission of power by high-voltage direct current. R. THURY. *Electrotech Z.*, **51,** 114–22 (1930).—T. gives a brief history and summary of the advantages of direct current for transmission, and discusses the use of the series connection of rotary converters, mercury rectifiers, and the transvertor for producing high-voltage direct current. M.A.B.

Long distance d.-c. transmission of power with Thyratron tube. ANON. *Power*, **72** [5], 190 (1930).—Laboratory experiments demonstrate the feasibility of using d.-c. transmission with consequent increase in efficiency and economy. The Thyratron tube, of the three electrode type, differs from the Pliotron tube in being an arc rectifier in which a power arc is controlled electrostatically by the grid. In its control function it will economically handle relatively large amounts of power. H.W.A.

Transmission loss in long power lines. L. LENG. *Electrotech. Z.*, **51,** 278–83 (1930).—L. applies normal transmission theory to power lines, deduces data for suitable loading and losses, and gives a method for graphically treating related problems. M.A.B.

Construction of motor-control apparatus with respect to motor control and short-circuit control. A. COHN. *Electrotech. Z.*, **51,** 233–38; 283–86 (1930).—A description is given of the latest AEG patterns of contactor control for motors. Overload protection on a thermal basis is discussed. M.A.B.

Weighing hoppers and scales. New tool for precise concrete control. P. M. TEBBS. *Eng. News-Rec.*, **104** [14], 560 (1930).—T. discusses the proportioning of concrete aggregates by weight, and describes various types of batch weighing hoppers and scales, drawing attention to salient points in the design of such plant with special reference to devices for eliminating as far as possible errors due to the human element. W.L.

Device for determining bulking of sand. ANON. *Eng. News-Rec.*, **104** [18], 674 (1930).—A brief description is given of a bulkometer consisting of a glass vessel having three scales corresponding to 1:3, 1:2½:5, and 1:2:4 mixes. The vessel is filled loosely to a gage line with moist sand, which is thoroughly inundated and allowed to settle. The height of sand after settling indicates on the appropriate scale the volume required for a true mix. W.L.

Marl-extracting machine. ANON. *Engineering*, **130** [3364], 13 (1930).—The description and operation of a machine designed for extracting marl from the deep underlying layers of alluvial land and for bringing this material to the surface without the great disturbance and heavy labor employed in digging, is taken up. A.A.

New regulating valves. ANON. *Ceram. Ind.*, **15** [1], 82 (1930).—A "Micro-Vernier Oil Regulating Valve" for use with any fuel oil at any operating pressure gives instant and positive control of the oil burner and does not clog. There is a scale on the valve for use in setting. W.W.M.

Melting furnace fired by coke or oil. ANON. *Brass World*, **26** [7], 185 (1930).—Monarch Eng. & Mfg. Co. has a metal melting furnace which can be changed to use either gas, oil, coke, coal, or wood for fuel. Coke can be used in combination with oil to produce high efficiency and save time. E.P.R.

Electrically-heated hardening and tempering baths compared with fuel methods of heating. WIRT S. SCOTT. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 129–35 (1930).—Warren Axe and Tool Co. replaced fuel-heated furnaces with electrically-heated types.

The new equipment will pay for itself in 18 months. Its control and operation are described. See also *Ceram. Abs.*, 9 [10] 869 (1930). E.P.R.

Influence of casting practice on physical properties of die castings. CHARLES PACK. *Mining and Met.*, **11** [284], 30 (1930).—There is a growing recognition of the importance of the metallurgical phase in designing die-casting machines. Future development of die-casting equipment may be expected to comply with metallurgical practice. E.J.V.

Resistance of metals suitable for dies to the abrasive action of plastic clay. ANON. Bur. Stand., *Tech. News Bull.*, No. 159, pp. 69–70 (1930).—The purpose of this investigation is to obtain data on the "wearing qualities" of different metals and alloys under measurable conditions simulating those of the stiff-mud process of forming clay products. Up to the present, 12 metals and alloys have been tested. A comparison of the weight losses per unit of volume of clay-sand mixture extruded and calculated on the basis of "unity" for the average of chromium-nickel-tungsten compositions which were most resistant to abrasion of the specimens tested are as follows: (1) carbon-cobalt-chromium, 2.33, (2) average for several cast irons, 30.96, (3) carbon-chromium-nickel steel, 39.13, (4) electrolytic carbon, 161.00, and (5) manganese-zinc bronze, 276.80. The nitriding of steel produces a hardened "wear-resisting" surface which decreases in hardness with depth. R.A.H.

The DDE: new research microscope for the scientist. R. W. ABELL. *Amer. Jour. Public Health*, **20** [6], 654–55 (1930).—A description of the new Bausch & Lomb binocular microscope. See also *Ceram. Abs.*, 9 [5], 366 (1930). E.J.V.

Cartons for pottery. ANON. *Pottery Gaz.*, **55** [638], 1267 (1930).—Showing how package goods is sold largely through the use of a branded package, an effort is made to present the cardboard box to the notice of potters as a medium for establishing valuable contact with their ultimate public, and with which they may effect better methods of trading for the wholesaler and retailer. E.J.V.

Researches on the electro-deposition of chromium. O. MACCHIA. *Chem. News*, **141** [3664], 1–7 (1930).—The brightness of chromium deposit depends upon the thickness of the cathodic film and on the quantity of SO_4 ions present at the given temperature. The thickness depends upon the current density and temperature, since with a rise of temperature it tends to become thinner. See also *Ceram. Abs.*, 9 [9], 791 (1930). G.R.S.

Chromium plating. J. COURNOT. *Mém. compt. rend. soc. ing. civils France*, pp. 303–11 (1928); *Jour. Inst. Metals*, **40**, 628.—Methods of overcoming difficulties are suggested. See following abstract. (*C.A.*)

Chromium plating. J. COURNOT. *Usine*, **37** [4–5], 21–23 (1928); *Jour. Inst. Metals*, **42**, 557.—Concentration of the bath is 250 g./l.; the electrolyte is H_2CrO_4 with additions of Cr sulphate, chlorides, nitrates, fluorides, and borates; current/density is 15 to 25 amperes/sq. decimeter and the working temperature, 50°. The advantages of this method are great hardness of the coating, high resistance against friction and corrosion, and a well-adhering coating. (*C.A.*)

Chromium plating. CHARLES H. PROCTOR. *Monthly Rev. American Electroplaters' Soc.*, **16** [8], 23–31 (1929); *Jour. Inst. Metals*, **42**, 579.—A review of the development of Cr-plating. (*C.A.*)

Chromium-plating die-cast metal. B. F. LEWIS. *Monthly Rev. American Electroplaters' Soc.*, **16** [4], 20–24 (1929); *Jour. Inst. Metals*, **42**, 578.—Zn-base die-castings must be thoroughly cleaned and plated with Ni prior to plating with Cr. The Ni-plating bath should have a p_H of 6.0 and be free from suspended matter and dissolved Fe salts so as to avoid the production of pinholes in the deposit and subsequent incomplete covering with Cr. (*C.A.*)

Some facts about chromium plating. JACOB HAY. *Monthly Rev. American Electroplaters' Soc.*, **16** [5], 5–19 (1929); *Jour. Inst. Metals*, **42**, 577.—The paper contains details for cleaning and Ni-plating brass-ware prior to Cr-plating, methods of determining H_2SO_4 and H_2CrO_4 in plating baths, and a discussion of the causes of faulty work with several baths, the composition of which is given. (*C.A.*)

Remarks on chromium plating. EMIL GÖTZ. *Metallwaren-Ind. u. Galvano-Tech.*, **27**, 70 (1929); *Jour. Inst. Metals*, **41**, 562–63.—In Cr-plating articles that receive a preliminary Ni coating, the latter should be produced under such conditions that it contains the minimum of occluded H. G. recommends a bath temperature of 27° and a final washing with dilute soda, then with hot water. Badly plated articles may be stripped by immersion in 1:5 to 1:10 HCl. For testing the density of the Cr deposit on Fe or steel articles, they are immersed in a solution containing 50 g. of H_2SO_4 and 50 g. of $CuSO_4$ per l.; any pinholes in the deposit appear as red specks. (*C.A.*)

Packing for transport. J. W. PARKER. *Glass*, **7** [6], 244–46 (1930).—The origin of the use of fiberboard for packing and shipping in Great Britain is discussed. The standard forms of fiberboard containers are described and specifications given. The making of wooden crates is described. H.W.A.

Steel crates used to ship hollow tile. ANON. *Brick Clay Rec.*, **77** [3], 151 (1930).—Steel crates, 8 ft. wide, 9 ft. long, and 5 ft. high, weighing 2800 lbs., and having a net load capacity of 26,000 lbs., are being used by the Central R. R. of New Jersey for handling hollow tile and similar commodities. The end panels are fixed while the side panels consist of steel channels which may readily be removed to facilitate loading and unloading. Transfer of the container between car and truck is effected through the medium of a crane equipped with a spreader. Illustrated. E.J.V.

Huggenberger tensometer. ANON. *Engineering*, **129** [3353], 502 (1930).—An accurate strainmeter designed and made by Huggenberger, of Zürich, which magnifies the actual strains by 1200, is described and illustrated. A.A.

Improvements in apparatus for gas analysis. H. A. BAHR. *Chem. Fabrik*, pp. 13–15 (1929).—A modified Czako absorption pipette is described; also an improved Orsat apparatus with which a complete analysis, including H and CH_4 can be made in 20 min. with an accuracy of 0.1 to 0.2%. See following abstract. (*C.A.*)

Determination of hydrogen and methane in the Orsat apparatus. HERBERT A. BAHR. *Arch. Eisenhüttenwesen*, **2**, 495–502 (1929).—Orsat apparatus, such as is used today in many laboratories with the glowing wire pipettes gives unreliable results because of oxidizability of the electrodes and the use of unsuitable confining liquids. If a saturated solution of NaCl is used as confining liquid and Au, or protected Hg, used as electrodes, satisfactory results can be obtained. A constant, slight negative error in the CH_4 determination indicates that when the combustion is accomplished by means of a glowing Pt wire, some oxidation product other than CO_2 is formed, possibly $HCHO_2$ or HCHO. Two new modifications of the Orsat apparatus are shown, which are designed especially to overcome the errors encountered. See following abstract. (*C.A.*)

New Orsat apparatus for rapid and exact gas analyses. HERBERT A. BAHR. *Gas u. Wasserfach*, **73**, 440–44 (1930).—The design and operating details are given for a new type of Orsat apparatus (see 2 preceding abstracts) of design similar to that of the U. S. Steel Corp., except that the absorption and combustion portions are assembled in separate frames. Separate Cu oxide ovens are used for burning H (at 300°) and methane (at 900 to 1000°). O is used as the displacing gas. Acidified salt solution (colored by use of an indicator) is used as the displacing liquid in the capillaries and burette. Safety means are provided to prevent salt solution from entering the Cu oxide furnaces. With this apparatus a coke-oven gas analysis can be made in 20 min. or less, with an accuracy within 0.1 to 0.2%. (*C.A.*)

BOOKS AND BULLETIN

Gages and Fine Measurements. Vols. I and II. F. H. ROLT. Edited by R. T. Slazebrook. Macmillan and Co., Ltd., London. Price 42s net. Reviewed in *Engineering*, **129** [3362], 806 (1930); for abstract see *Ceram. Abs.*, **9** [1], 54 (1930). A.A.

A History of Mechanical Inventions. A. P. USHER. McGraw-Hill Publishing Co., Ltd., London. Price 25s net. Reviewed in *Engineering*, **128**, 445 (1929). A.A.

Wire saw in slate quarrying. OLIVER BOWLES. Bur. Mines, *Tech. Paper*, No. 469, 31 pp., 16 figs., 15¢. R.A.H.

PATENTS

Viscosimeter. JOHN MONTGOMERY BELL. U. S. 1,772,028, Aug. 5, 1930. Means for testing the viscosity of liquids, which comprises relatively rotatable members adapted to be immersed in a body of liquid to be tested, means for driving one of the members whereby the rotary motion thereof will be imparted to the other of the members through an intervening portion of the liquid, means for moving the members apart to a distance where the intervening liquid will cease to be effective in transmitting the motion from the driving member to the driven member, and an indicating means operative with the driven member to indicate the absolute viscosity of the liquid when the driven member ceases to rotate.

Conveyer for plastic materials. ALPHEUS O. HURXTHAL. U. S. 1,772,423, Aug. 5, 1930. In a foraminous conveyer for plastic materials, the combination of a plurality of relatively movable link sections coöperatively forming material receiving openings having relatively movable walls adapted to eject the material from the openings when the link sections are relatively moved.

Molding tile, etc. H. DRUART. Brit. 329,912, July 23, 1920. Tile are molded and decorated automatically and continuously. A series of molds, *e.g.*, twenty-four, are spaced radially on the intermittently-rotating table. A pattern plate is placed automatically into each mold and the colors run into a large number of molds simultaneously from color boxes on an upper table having a to-and-fro angular motion. Each mold comprises a rectangular box frame secured to the table by outwardly-projecting flanges.

Electric furnace. HAROLD E. WHITE. Can. 300,976, June 10, 1930. An electric furnace for the production of SiC is disclosed. (*C.A.*)

Kilns, Furnaces, Fuels, and Combustion

Single-chamber kilns in ceramics. CARL LOESER. *Sprechsaal*, **63** [27], 503–505; [28], 519–22 (1930).—L. reviews the literature on heat management and gives data on American and German investigations. M.V.K.

Single kilns and their use. A. NAWRATH. *Tonind.-Ztg.*, **54** [54], 892–93 (1930).—Single kilns with a periodical operation are used for firing products of high quality as they provide careful firing and smoking of the ware which is therefore free from cracks and is purer in color. The two kinds of single kilns are (1) kilns with horizontally directed flames and (2) kilns with vertically directed over-head flames. The first are called "flame kilns" and when fired correctly and carefully, the ware obtained is of very good quality and the consumption of fuel is low. These kilns can have one, two (double-flame kilns), or four chambers. The latter have the advantage of firing, simultaneously, ware requiring different treatment, which is impossible in an annular kiln. The second type of kiln is used for firing ware requiring high temperatures, such as iron clinker, grog ware, salt-glazed clay pipe, and ware which cannot come in contact with fuel. To

lower the consumption of fuel in single kilns, several kilns are joined by underground pipes and the escaping hot gases are conducted from one kiln to another and serve for preheating and smoking the ware. M.V.K.

Insulation of cement kilns results in increased firing efficiency. G. E. GRIMSHAW. *Pit and Quarry*, **20** [8], 77–78 (1930).—The rotary kiln is subjected to high temperatures, rotation, vibration, abrasion, moisture, expansion, and contraction of the firebrick lining and a continued impact of the heavy mass of clinker throughout the kiln. For these reasons, the insulating of rotary cement kilns involves risk. In 1924, a special block insulation was given a severe trial in a cement kiln. This kiln has operated almost continuously with only periodical shut-downs for renewing fire brick at the hot zone where insulation is not installed. The insulating material is yet in perfect condition. E.P.R.

Insulation of round downdraft kilns. A. F. GREAVES-WALKER. *Refrac. Jour.*, **5** [58], 388 (1930).—Tests of kilns with insulated walls and crowns show a fuel saving of 9% when only $4^1/_2$ in. of insulating brick are used in the walls and 2 in. on the crown. Complete insulation including bottoms is reported as showing fuel saving as high as 20% with a reduction of firing time and larger percentage of No. 1 ware. Proper insulation of the kiln bottom makes it easier to obtain uniform temperatures throughout the kiln, resulting in a more uniform product. E.P.R.

Heat in Hoffman and tunnel kilns. ANON. *Brit. Clayworker*, **39** [459], 127 (1930).—A tunnel kiln in which the ware is carried on cars loses less heat through the walls than any other form of continuous kiln. It is little realized how much heat is lost in an ordinary Hoffman kiln. Much heat is required to produce a draft in such a kiln and to replace that lost by radiation. A tunnel kiln with cars needs less fuel than a Hoffman or similar kiln because each stage of firing takes place in a definite part of the kiln so that there is little loss of heat through the bottom and the loss by radiation is far less. It is wrong in principle to endeavor to restrict the air passed through a continuous kiln to that needed to burn the fuel. The total quantity of air required for efficient operation is about 12 times that needed theoretically for combustion. R.A.H.

Fuel utilization in the ceramic industries. I. A. T. GREEN AND A. J. DALE. *Engineering*, **128,** 582 (1929); for abstract see *Ceram. Abs.*, **9** [2], 121 (1930); for Part II see *Ceram. Abs.*, **9** [3], 223 (1930). A.A.

Firing clay ware. HEWITT WILSON. *Fuels and Fur.*, **8** [2], 181–86 (1930).—After outlining the properties of an ideal ceramic body, W. describes the properties of the common ceramic raw materials and the bodies made from them. The origin of clays and the differences between white-, buff-, and red-firing clays are described. The chemical and physical changes which take place during drying and firing are given in detail and the causes of fired strength are listed. The various stages in firing and their purposes are given and the precautions which should be taken are explained. The importance of flame temperature when firing clays with a short vitrification range is stressed. The development of color is described in detail. Data recently collected by the Pacific Northwest Clayworker's Assn. are used in a discussion of fuel costs. Comparative fuel costs for different types of kilns are given and the question of lowering the fuel costs is taken up. The importance of accurate heat balances is stressed and the methods and instruments which should be used in getting heat-balance data are described. The main heat losses are listed and methods for minimizing them are discussed. A.E.R.W.

Rapid-fire tunnel kiln used in production of small ware. A. L. DONNENWIRTH. *Fuels and Fur.*, **8** [3], 385–86 (1930); for abstract see *Ceram. Abs.*, **9** [3], 220 (1930). A.E.R.W.

Willard Kittanning Brick Mfg. Co. ANON. *Brick Clay Rec.*, **77** [2], 89–94 (1930).—One of the outstanding tunnel kiln installations of the face-brick industry is found at the Willard Kittanning Brick Mfg. Co., Kittanning, Pa. The tunnel kiln unit embodies

several unusual features, *e.g.*, the preheater in which the ware, set on kiln cars, is raised to 300° before entering the kiln, a special type of recuperator for reclaiming waste heat from the kiln to use in the preheater and driers, and the design of the kiln itself. Full details of the construction and equipment of the plant are given. Illustrated. E.J.V.

Ovens for high temperatures. J. D'ANS. *Chem. Fabr.*, pp. 41–43 (1930).—A summary of an address by R. Otto on the development of small high-temperature ovens for use in oxidizing atmospheres at 2000° or over, especially the gas oven with ZrO_2 lining. (*C.A.*)

Oven for high temperatures. ST. REINER. *Chem. Fabr.*, pp. 101–102 (1930).—Directions are given for constructing a resistance furnace for temperatures up to 2200°. See preceding abstract. (*C.A.*)

Repairs to a continuous-fire kiln when not in operation. J. WELTER. *Rev. mat. constr. trav. pub.*, No. 249, pp. 104–106B (1930); see also *Ceram. Abs.*, **9** [9], 764 (1930). A.J.M.

Improvements for tunnel kilns. FRANCART-DURIEUX. *Chaleur ind.* [Special No.], pp. 254–55 (April, 1930). A.J.M.

Arch of the firing channel. ANON. *Tonind.-Ztg.*, **54** [55], 906–907 (1930).—A discussion of the stability and the most favorable curvature for the arch of the firing channel is given. M.V.K.

Recuperation of waste heat. L. NISOLLE. *Chaleur ind.* [Special No.], pp. 59–67 (April, 1930). A.J.M.

Improvements in firing. A. BIGOT. *Corriere ceram.*, **11** [5], 209–17; [6], 231–37 (1930).—The following researches based on laboratory experiments were made: (1) calculations of the calories used in kilns; (2) study of a tunnel kiln of 30 m.; (3) improvements in tunnel kilns and drying installations; (4) fuels and preparations for firing; and (5) application to different industries. M.V.K.

Stream-line filtration. ANON. *Engineering*, **128**, 421–22 (1929). A.A.

Tests with a regenerative chamber. HANS KISTNER. *Stahl Eisen*, **50** [29], 1027–28 (1930).—K. describes his tests, the results of which showed that the building of heat exchangers depends on the economic increase of the convective heat transfer. This can be obtained by using a greater velocity of gas in the chamber with the least possible loss of pressure in the inlet channels, and often without additional ventilator power. M.V.K.

Standard shatter test for coke. ANON. *Engineering*, **129** [3360], 745 (1930). A.A.

Physics in relation to utilization of fuel. C. H. LANDER. *Engineering*, **128**, 844–45 (1929).—Fuel problems are divided into three sections: (1) the preparation and specification of the fuel, (2) the treatment prior to combustion, and (3) fuel utilization. Coals are commonly classified upon the basis of volatile content, flaming characteristics, and ultimate analysis. Attention is also given to the physical structure. The aid of a microscope is utilized for the examination of thin sections by transmitted light, and for the study of polished and etched surfaces by reflected light. By means of X-rays, the presence of graphite in all types of coke examined is demonstrated. The necessity for a more general adoption of coal cleaning is becoming more apparent even with high quality, clean coal. The methods in use depend upon differences in the physical properties of coal substance itself and its impurities, differences in density, size, shape, surface tension, etc., relative to water and other liquids. Mechanical principles underlying the jigs and bashes, the retort carbonization, and physics of the furnace are also taken up. A.A.

Instruments and apparatus. ANON. *Mech. Eng.*, **52** [8], 797–98 (1930).—Pre-

liminary draft of Part 3—temperature measurement; Chapter 5, pyrometric cones. The Main Committee on Power Test Codes presents to the members of the A.S.M.E. this draft for criticism and comment. The description and classification of Orton cones is given. Advantages and disadvantages are listed. The range of temperature is approximately 1100 to 3600 °F. The accuracy depends upon furnace conditions, rate of heating, care in manufacture, the mounting and position of cones, and the personal error in judging the end-point. The preparation and procedure for making a test to determine the pyrometric cone equivalent of refractory materials is given. The factors which control the actions of cones are classified. H.W.A.

"Super" gas furnace. ANON. *Mech. World*, **87** [2269], 607 (1930).—A new type of gas-fired furnace has been constructed by the Incandescent Heat Co., Ltd., Birmingham. The furnace is fired by patent incandescent natural-draft adjustable jet gas burners, each under separate control, working in conjunction with a multi-combustion chamber system. Unit recuperators are arranged below the furnace hearth, and are built on the block principle, five silicon carbide tubes, 9 in. long by 2 in. in diameter, being fitted to each burner; there are six sets of these tubes in the furnace. The furnace is constructed in a heat-resisting cast-iron casing, lined with 12-in. thick Sil-O-Cel insulating material; Scotch firebrick material is used for lining the working chamber. E.P.R.

Relative places of gas and electricity in industrial heating. R. A. HADFIELD. *Gas Jour.*, **191** [3504], 157–58 (1930).—Gas furnaces are cheaper in fuel cost, but electric furnaces give the higher thermal efficiency. A gas-fired furnace is the most flexible of all furnaces. Time-temperature relation of the heating operation largely governs the question of suitability. Automatic control has just come to the fore in gas-fired furnaces. G.R.S.

Electricity and gas for pottery firing. ANON. *Pottery Gaz.*, **55** [638], 1300 (1930).—There are seven electrical kilns now in operation at potteries in the Stoke-on-Trent district, consuming, in the aggregate, 2,295,000 units annually, or more than the whole of the bulk supplies furnished to neighboring local authorities. The City Gas Department of Stoke-on-Trent also reports that Corporation coal gas is now being requisitioned to assist producer gas in the firing of electrical porcelain in a continuous tunnel kiln at one of the important potteries. E.J.V.

Is electric heat economical? W. S. SCOTT. *Elec. World*, **96** [5], 213–15 (1930).—Electric heating should be sold on the basis of economy. A survey was made of users of electric furnaces doing various kinds of heat treatment to find the cost of operation. Substantial savings were shown by a study of data and records. Examples of the methods used in the investigation are given in tables containing records of four companies. See also *Ceram. Abs.*, **9** [4], 302 (1930). G.R.S.

Smoke abatement research in Sheffield. ANON. *Engineering*, **129** [3352], 487 (1930). A.A.

Expenditure of heat in carbonization of coal. E. TERRES. *Gas u. Wasserfach*, **72**, 361–69; *Mech. World*, **88** [2270], 17 (1930).—T. states that the requirements of modern carbonizing plants range from 420 cal. per kg. (755 B.t.u. per lb.) of air-dry coal in the latest type of coke ovens to 715 cal. per kg. (1290 B.t.u. per lb.) in retort settings, excluding producer losses. The efficiency of the process is determined from a knowledge of the "heat of carbonization." The "heat of carbonization" is determined experimentally in a specially designed calorimeter, which also permits determination of the "heat of carbonization" of the coal. The relationship between the two is illustrated by a curve. Coking coals usually possess a negative "heat of carbonization" and thus a high "heat of carbonization," while the reverse is the case with most gas coals. It has thus been found that the carbonizing process has an efficiency of 52 to 67%. The diffusivity for three types of coal has been determined for a temperature range of 20 to 1000°C (68

to 1832°F), and the carbonizing time can be computed from a formula which is given for coke ovens. E.P.R.

Hayes process low-temperature carbonization plant. J. D. McQUADE. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 153–55 (1930).—Low-temperature carbonization was adopted at Moundsville, W. Va., so that the large percentage of slack and screenings could be converted into a merchantable fuel. The process adopted had to meet the requirements of being operated over long periods and be free from carbon formation when working high-volatile bituminous coal; the retorts must be of a design to permit easy repair with a minimum of time and labor; the process must be automatic; it must yield tar and gas as by-products. Operating costs and returns have been such that the unit will be expanded for a much larger output. E.P.R.

Carbonization-plant "Lurgi" process. MAX TOLTZ. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 149–52 (1930).—The first operating installation of the German "Lurgi" process for treating low-grade fuel has been made at the Lehigh (N. D.) Briquetting Co. The process is particularly adapted to N. D. lignite, and the carbonized-coal residue, with pitch by-product as a binder, is pressed into merchantable briquets, which burn as a smokeless fuel with high recoverable heat value. E.P.R.

Low-temperature carbonization under pressure. A. THAU. *Glückauf*, **65**, 1728–34; *Eng. Abs.; Mech. World*, **87** [2269], 614 (1930).—T. describes briefly the progress of low-temperature carbonization, and states that if this process shall yield economic results it is necessary to obtain the product in the form of briquets suitable for the market. He describes the appliances invented by Tormin, of Düsseldorf, which are devised for the treatment, respectively, of caking coal by a continuous process, of noncaking coal by a continuous process, and of caking coal by a noncontinuous process. E.P.R.

Evolution of low-temperature carbonization. CH. ABD-ER-HALDEN. *Chaleur ind.* [Special No.], pp. 45–53 (April, 1930). A.J.M.

Economics and commercial development of low-temperature carbonization in Great Britain. C. H. LANDER. *Colliery Guardian*, **140** [3626], 2402–2403 (1930).—Data used in estimating the commercial success of the various low-temperature carbonization processes are presented and discussed. E.J.V.

By-products from the carbonization of coal. T. J. ESS. *Blast Fur. Steel Plant*, **18** [8], 1287–92 (1930).—E. lists the many reactions that take place when coal is converted to coke, and gives their values. Illustrated. E.J.V.

Complete gasification of coal. R. MEZGER AND T. PAYER. *Gas u. Wasserfach*, **73**, 1–8 (1930); *Gas Age-Rec.*, **66** [3], 78 (1930).—The "double-gas" process for complete gasification provides a valuable adjunct to existing methods of gas production, mainly in respect to the rapidity with which the plant can be brought into operation and the ease with which the gas so produced may be blended with coal gas, producer gas, etc., to give a mixture of the desired calorific value. The manner in which the plant is operated is described in detail and particular attention is paid to the technical difficulties that are encountered during the operation of the complete gasification combined retort and gas generator. A study is made of the behavior of the coal in the retort as well as of the carbonized mass which drops down into the generator. The difficulties of operation are connected with the properties of the coal used. Diagrams are given and results obtained in testing various coals are tabulated. Assistance in evaluating a coal as to its suitability is given in recommendations for the limiting values obtained by the various tests with special reference to swelling and caking, which greatly affect the working of the "double-gas" plant. E.J.V.

Slacking of coal. ANON. *Gas Age-Rec.*, **66** [3], 88 (1930).—A study of the slacking tendency of coal is being conducted by the U. S. Bureau of Mines at Pittsburgh. An accelerated test method is being applied to coals varying in rank from the highest to the

lowest. By this method it is indicated that (1) bituminous coals show very little tendency to slack; (2) there is no close relation between slacking tendency and bed moisture; (3) in general, slacking increases with decrease in rank from high moisture bituminous coals to lignites. E.J.V.

Sampling coal from unit pulverizers. R. S. JULSRUD. *Power*, **69**, 673; *Mech. World*, **87** [2261], 415 (1930).—J. describes five methods of obtaining samples of the coal dust passing through a delivery pipe with the current of air from a fan. The best results were obtained by the use of a 1-in. diameter tube fitted at the end with an elbow, the edges of which were sharpened. The elbow faced the current of air and dust. The other end of the pipe on which it was fixed led to a small cyclone separator from the top of which a vacuum cleaner abstracted the air, drawing it through a filter can packed with wood shavings. During the test the pipe was slid in and out so as to take a series of samples at ten points along each of two diameters of the delivery pipe at right angles to one another. With negative pressures in the sampling tube of 0.05 in., 0.1 in., and 0.2 in., the percentages passing a 200-mesh screen were 63.8, 64.1, and 62.8, respectively, the missing quantities having been caught by screens of more open mesh on all of which the coal dust was sifted in succession. Sectional drawings illustrate all the arrangements tested, and the results are tabulated. E.P.R.

Bituminous coal cleaning plant. ANON. *Engineering*, **130** [3367], 102–103 (1930).—One of the coal-cleaning plants of the Pittsburgh Coal Co., the Warden, is described and illustrated. A.A.

Coal cleaning. ANON. *Engineering*, **129** [3351], 449 (1930). A.A.

Manufacture of coal briquets. ANON. *Colliery Guardian*, **140** [3626], 2399–2402 (1930).—Many attempts have been made to employ sulphite lye as a substitute for pitch as a binder for coal fines with varying success. The greatest difficulties encountered, however, have been to produce a briquet with lye as a binder which shall possess with consistency good burning qualities, impermeability to moisture, and considerable mechanical strength. This has been accomplished. Data on fuel efficiency tests run to compare these briquets and anthracite are presented. Illustrated. E.J.V.

Agglutinating value of coal. K. A. JOHNSON AND H. F. YANCEY. *Gas Age-Rec.*, **66** [2], 65–68 (1930).—This report presents some important variables, their effect on the agglutinating value obtained, and a comparison of results obtained in different laboratories by careful adherence to the procedure outlined by Marshall and Bird. Further work on the development of a satisfactory test is still in progress in the Bureau of Mines laboratories. These studies may change the character of the test. E.J.V.

Reactivity of coke. D. J. W. KREULEN. *Brennstoff-Chem.*, 169 (1929); *Gas Age-Rec.*, **66** [2], 50 (1930).—Reactivity is determined by passing air over a sized coke sample in a platinum boat heated in an electric tube furnace. After charging, the sample reaches the furnace temperature in two minutes. Air is then passed for five minutes at 20 liters per hour and the CO_2 is absorbed and weighed. Reactivity is expressed in mg. CO_2 formed per sq. cm. coke surface exposed. In controlling the area of coke exposed, the effect of particle size and that of blanketing of the coke by CO_2 previously formed were eliminated; only the reaction velocity is determined, which is called the true reactivity of the coke. Curves show a wide variation in reactivity for different cokes within the range 500 to 600°, but a small variation at 800°. The main conclusion is that at 800° and above, the true reactivity for all cokes is practically the same. E.J.V.

Influence of iron compounds on reactivity of coke. J. H. JONES, J. G. KING, AND F. S. SINNATT. *Colliery Guardian*, **140** [3626], 2447 (1930); *Gas Age-Rec.*, **66** [5], 183–84 (1930).—The influence of inorganic constituents of the coke, particularly iron, on its reactivity to carbon dioxide is discussed. It is shown that the iron in coke, and the form in which the iron is present, has a marked effect on the reactivity. E.J.V.

Coke quality of splinty coals. ANON. *Gas Age-Rec.*, **66** [3], 80 (1930).—Work on the coke- and gas-making properties of coal now in progress indicates that weak coke is produced from splinty coals at high-carbonizing temperatures (corresponding with coke- and gas-works practice), but when made at lower temperatures the coke is not inferior to that from coals of similar rank containing no splint coal. E.J.V.

Progress of gas producer technology. H. GUILLON. *Chaleur Ind.* [Special No.], pp. 29–44 (April, 1930). A.J.M.

Combustion of powdered coal. E. A. *Chaleur ind.*, **11**, 268–76 (1930).—The proper types of furnaces are discussed and described. A.J.M.

Relative inflammability of coal dusts. ANON. *Engineering*, **129** [3353], 536 (1930). A.A.

Forced-draft firing of pulverized fuel. OLLISON CRAIG. *Power*, **71** [25], 991–93 (1930).—The two general methods of supplying secondary air for burning pulverized fuel are (1) introducing air under pressure, commonly known as forced-draft firing and (2) utilizing the furnace suction, or natural draft firing. The forced draft is being used on most of the new unit pulverizer installations. Forced-draft secondary air is introduced through the burners, making the horizontal burner better adapted. The air may be preheated if desired. In summarizing the advantages of forced-draft over natural-draft firing, experience has shown that the former produces greater turbulence and more complete mixing of secondary air with the primary mixture than is possible with natural draft; maintains more effective mixing at all rates; is more susceptible to easy and quick control and more adaptable to automatic control, affording greater flexibility in operation. Forced draft firing also (1) provides means for obtaining and maintaining any desired CO_2; (2) permits development of greater steam capacity and operation at lower minimum load with continuous firing; (3) results in less setting leakage; (4) affords greater heat absorption from the gases and less carbon loss; (5) secures lower exit temperature of gases; (6) provides greater over-all efficiency of steam generation; and (7) reduces cost of steam through reduced fixed charges per unit of capacity. H.W.A.

Revised regulations for pulverized fuel. ANON. *Power*, **72** [4], 150–51 (1930).—The regulations adopted by the National Fire Protection Assn. governing pulverized fuel installations, in relation to fire protection, have been changed to conform with present practice and new designs. The changes mostly concern unit systems and driers. H.W.A.

Sampling of pulverized fuel. HORACE C. PORTER. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 111–14 (1930).—Pulverized fuel is sampled particularly to determine its fineness. The fineness has much influence on performance. It is also necessary to know the percentage of ash, volatile matter, and moisture, and the character of the ash in respect to fusion tendencies. A.S.T.M. (D 197–26 T) specifies a method of sampling from the air stream in a pipe. The three main systems for firing powdered coal are (1) the unit system, in which the powdered fuel is blown directly from the pulverizer into the furnace without intervening storage; (2) where the coal is pulverized some distance away from the furnaces; and (3) where the pulverized coal is stored in bins. E.P.R.

Use of pulverized fuel. J. T. DUNN AND BURROWS MOORE. *Queensland Govt. Mining Jour.*, **31** [6], 243–48 (1930); for abstract see *Ceram. Abs.*, **9** [7], 560 (1930). E.P.R.

Thermodynamics of combustion of pulverized fuel. P. ROSIN. *Colliery Guardian*, **141** [3628], 132 (1930).—R. deals with the idea of load or capacity of a furnace and the factors on which it depends. The load of a furnace is the number of calories developed in it per cu. m. when the combustion is complete and continuous and inclusive of the preheating. In 1925, R. developed the first load equation, *i.e.*, $B = 3600\ H_u/V_{cs}$

(kg.-cal./kg.), in which H_u denotes the lower calorific power of the fuel in kg. cal./kg., V_t the volume of gas evolved from 1 kg. of fuel (in cu. m.) at absolute temperature, T, of the furnace, z the time of burning in seconds of the largest particles of the fuel. This can be written as $B = 33{,}800/z$ (kg.-cal./cu.m.), with certain assumptions, and shows that the load problem is one of velocity of burning of the fuel particles. The time of burning, z, depends on many chemical and physical reactions which cannot be mathematically expressed, but the influence of three of the most important of these is dealt with, *viz.*, (1) fineness, St, of the fuel; (2) temperature, T; (3) total hydro- and aerodynamical processes, Ae, in the combustion chamber. Thus $1/z = f(St, T, Ae)$, and $B = (\text{Const.}/T)/f(St, T, Ae)$. The effect of a variation in each of these three quantities is discussed in detail and curves are given showing the effects produced. It is concluded that combustion and transformation are complicated processes. Hence, it is impossible to single out one factor as the essential property of the fuel. To get the greatest load from the furnace, it is necessary to increase the transfer of heat at the cold and hot surfaces. This is as important as shortening the value of z, otherwise all the difficulties in connection with overloading appear. See also *Ceram. Abs.*, **9** [5], 372 (1930).

E.J.V.

Graphical determination of heat capacity of gases. A. ALISON. *Glass*, **7** [6], 236–40 (1930).—A knowledge of the heat contents of gases is necessary in problems relating to combustion, especially in regard to computing flame temperature, heat losses in the waste gases, and the extent of the recovery of heat that can be made from them. The basic equation for the chart is the one given by A. D. Williams in the appendix to "The Flow of Gases in Furnaces," based on the experiments of Mallard and Le Chatelier. $Q = a(T_1 - T_0/1000) + b(T_1^2 - T_0^2/1000^2)$; where Q = heat capacity in calories per g. mol. between the temperature, T_1 and T_0. T_1 and T_0 = temperature °C; a = constant equal to 6.5 for all gases; b = nitrogen, oxygen, hydrogen, and carbon monoxide 0.6; for carbon dioxide 3.7; for methane 6.0; for water vapor 2.9. Calculations of the heat contents of the various furnace gases at different temperatures can be computed from the formula, but if used frequently it may be convenient to set it down in nomographic form. The preliminary calculations necessary and a detailed explanation of the construction of the chart, as well as the chart itself, are given. H.W.A.

Liquefied petroleum gases as industrial fuels. R. W. THOMAS. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 143–48 (1930).—The object of the paper is to show (1) the general availability and the assured continuity of supply of large quantities of liquefied petroleum gases, (2) the adaptability of these fuels for exacting industrial processing such as heat treating and other operations of a highly refined nature, and (3) the advantages and limitations of liquefied petroleum gases in industrial fields, particularly from the economic viewpoint. E.P.R.

Rational cleaning of gas pipes. HANS NEUMANN. *Sprechsaal*, **63** [28], 524–25 (1930).—N. points out the importance of rational cleaning of gas pipes because solid or thick liquid residues are formed in regenerators by gasification of mineral coal, peat, wood, and certain kinds of brown coal which gradually narrow the diameter of the gas pipes. The period between the cleaning depends on the fuel used (formation of tar and flue dust) and on the arrangement of the pipes, and generator, etc., and must be done at least once in 5 weeks. Different methods of cleaning are discussed. M.V.K.

BOOKS AND BULLETINS

Modern Gas Producers. N. E. RAMBUSH. Glass Publication, London. 545 pp. 356 illustrations. Price 55/net.

Coal Dust Firing. (Kohlenstaubfeuerungen.) HERMANN BLEIBTREU. Reviewed in *Mining and Met.*, **11** [284], 20 (1930); for abstract see *Ceram. Abs.*, **9** [8], 669 (1930).

E.J.V.

Practical Heat Management: Short Outline of Losses of Heat and Re-Obtaining of Heat in Industry. (Practische Wärmewirtschaft. Kurzer Abris des Wärmeverluste und Wärme-Ruckgewinnung bei Industry- und Kraftanlagen.) HEINRICH FÖGE. Alfred Oppenberg, Hannover, 1929. 133 illustrations. 10.00 Rm. Reviewed in *Sprechsaal*, **63** [29], 552 (1930).—In the first part of the book, F. discusses different ways of utilizing waste heat and preventing losses of heat which occur in different installations. Diagrams illustrate the description. The second part describes the construction and management of waste-heat apparatus, economizers, flue-gas air heaters, waste-heat boilers, air heaters, and waste-steam heaters. F. explains that the selection of the most appropriate kind of waste-heat carrier is determined by the amount of waste heat and the temperature used. Tables explain the construction and action of different systems. The purpose of the work is to give a general review of the advantages of waste-heat utilization and means of achieving it. M.V.K.

Check determinations of fusibility of coal ash with the De Graaf electric coal-ash fusion furnace. W. A. SELVIG. Bur. Mines, *Rept. of Invest.*, No. 3003, 17 pp. (1930); *Gas Age Rec.*, **66** [3], 84 (1930).—The purpose of the investigation reported in this paper was to determine how closely different laboratories can check one another in making determinations of fusibility of coal ash with the De Graaf furnace, how well duplicate determinations by the same laboratory will check, and how the results with the De Graaf furnace compare with those of the standard gas-furnace method of the A.S.T.M. Nineteen coal ashes covering a wide range in ash fusibility were sent to five laboratories for fusibility determinations. The five laboratories reported, in general, wide differences in the fusibility of the same coal ashes as determined by the De Graaf method. This lack of agreement among the laboratories is a serious objection to the method for general use in determining ash fusibility. A comparison of fusibility results by the De Graaf method and the standard gas-furnace method shows poor agreement. R.A.H.

PATENTS

Brick kiln. DAVID J. STRICKLAND. U. S. 1,772,404, Aug. 5, 1930. A brick kiln having a box comprising a plurality of hollow units adapted to contain water, and means adapted to carry off from the units the steam generated therein.

Kiln floors. J. KNOWLES & CO. (WOODEN BOX), LTD., AND H. J. TAYLOR. Brit. 329,443, July 9, 1930. In a downdraft kiln for firing clay goods, "dead" areas above the supporting walls for the perforated floor blocks are eliminated by providing within the body of the blocks passages or perforations opening into the kiln chamber above the walls and so formed or arranged that heating gases can pass down through them into the floor flues. The vertical holes adjacent the walls are extended laterally by grooves or recesses in the upper faces of the block. Alternatively vertical holes above the walls may be extended at the lower faces of the blocks by lateral recesses, or the perforations may be inclined, curved, or flared.

Muffle furnaces. GIBBONS BROS., LTD., AND T. E. BRIDGFORD. Brit. 329,787, July 16, 1930. The roof and side walls of a muffle are formed by transversely arranged parallel tubes which communicate with a flue passage beneath the floor and are spaced from the enclosing walls of the furnace. Combustion products from a fireplace and hot secondary air are supplied to the space beneath the roof and enter the flue system of the muffle through apertures in the arched roof flues, from which they pass down the side flues across the floor, and up flues to the downcast flue, horizontal floor flues, and the waste flue. The secondary air is heated in flues alternating with the flues.

Kilns. EMIL PEIPMANN. Ger. 494,792, July 31, 1928. A round kiln for firing porcelain is described. (*C.A.*)

Rotary kiln. HARRY STEHMANN. Ger. 494,793, Oct. 19, 1926. (*C.A.*)

Heating ring and chamber kilns by a scattering hearth. MICHAEL BOHN. Ger. 495,859, Aug. 18, 1928. (*C.A.*)

Semi-automatic tunnel-furnace charging and drying apparatus. RUDOLF STELZER. Ger. 495,915, Dec. 6, 1928. Details of construction. (*C.A.*)

Kilns. STETTINER CHAMOTTE-FABRIK A.-G. VORM. DIDIER. Ger. 496,523, Sept. 27, 1928. The kiln is provided with spraying nozzles for testing the degree of fireproofness of objects. (*C.A.*)

Rotary kiln and heat recuperator. VICKERS, LTD. Ger. 497,389, Sept. 12, 1926. See Brit. 262,525 (*C. A.*, **21**, 3493). (*C.A.*)

Geology

Progress in the study of the clay minerals. EDGAR T. WHERRY, CLARENCE S. ROSS, AND PAUL F. KERR. *Colloid Symposium Annual*, **7**, 191–93 (1929).—X-ray examination indicates at least 3 main types of clay minerals, differing fundamentally in crystal structure: (1) kaolins; (2) montmorillonites; and (3) potash-bearing clays. These overlap considerably in silica:alumina ratio. (1) includes 3 species: (*a*) kaolinite, (Johnson). In this, the variations from the normal SiO_2:Al_2O_3 ratio of 2:1 up to sometimes 3:1 are not due to errors in samples or analyses, as rigorous microscopical examination proved. Important varieties are halloysite, anauxite, and beidellite. (*b*) "Kaolinite" (Dick). This must be renamed. It is the best crystallized and most constant in composition (ratio 2:1 strictly), and is rare in nature. (*c*) Nacrite (Breithaupt). It is chemically identical with the preceding, but rarer. In (2), montmorillonite (Salvetat), the original mineral had a SiO_2:Al_2O_3 ratio of 4:1, but variations range from 5:1 to 2:1, without change in structure and but small alteration in the X-ray unit cell. MgO is frequently present, apparently as an essential constituent. This is often produced by ejection of volcanic lavas, the glassy rock being subsequently altered to clay (bentonite). Potash-bearing clays (3) are not yet fully investigated; they occur in metamorphosed bentonites, in gouge-clays of some metalliferous veins (where often mistaken for sericite), and in altered igneous rocks. The X-ray pattern is distinctive. The SiO_2:Al_2O_3 ratio is fairly high, averaging perhaps 3:1 with several % K present. Kaolin (1) type clays are mainly used in ceramics, but the montmorillonite (2) type clays are most interesting colloid-chemically (having especially high adsorption) and are used for softening water, clarifying oils, etc. The X-ray shows that molecular structure rather than chemical composition is the controlling factor. Further work is in progress. See also *Ceram. Abs.*, **9** [5], 375 (1930). (*C.A.*)

Weathering of granites. LUKA MARIĆ. *Arhiv Hem. Farm.*, **3** [4], 183–87 (1929).—M. examined a fresh and weathered andalusite granite from the quarry in Jugoslavia, both microscopically and chemically. According to the chemical analytical proof, the chemism of the granites was not appreciably altered by the weathering, even if the weathering had proceeded to such a degree that the weathered granite could easily be crushed and crumbled with the fingers. The content of Fe_2O_3, K_2O, and H_2O increased due to the weathering. The increase in K_2O was considerable. The decrease of Na_2O and CaO in the oligoclase, which has less resistance to weathering than orthoclase, was not so great. The content of SiO_2 and Al_2O_3 remained practically unchanged. The weathering of the andalusite granites can generally be traced back to kaolinization and hydration. These investigations are of considerable importance in the problems of soil formation. E.J.V.

Constitution of ultramarine. F. HOFFMANN. *Z. anorg. allgem. Chem.*, **189** [1], 91–100 (1930); *Sprechsaal*, **63** [30], 564 (1930).—Ultramarine and substrates of ultra-

marine were exposed to α and β rays of radium chloride; 2 Al are liberated by the ultramarine transformation of sodalithe $Na_8Al_6Si_6O_{24}Cl_2$; a resistant component is present, $Na_4Al_4Si_6O_{24}$, which reacts in the presence of sodium sulphite as $Na_6Al_4Si_6O_{24}$. The coloring is influenced here by liberated Na constituents or atoms, in the opinion of H. The ultramarine substrates produce characteristic irradiation effects according to their chemical composition; the colors blend in a different direction from that produced by sulphur. In white-green and violet-ultramarine, changes of color no longer appear when exposed to rays if the return of the dissociated sulphur to the original combinations is prevented in blue ultra-marines. In general, with the exception of the replacement of alkalis by different metal-ions, ultramarine coloring is stronger in coloring power in proportion to the increase in its SiO_2 and sulphc-polysulphide content. W. sees the sulpho-polysulphide as the case of the coloring in blue-ultramarine; by the ultramarine process the sulphur is removed from the original sulphide and cannot recombine because of a change in the proportion of combination. It then changes into the colloidal or pure solution state. M.V.K.

Transfusion of matter from one solid to another under the influence of heat: a new factor in the process of metamorphism. F. D. ADAMS. *Can. Jour. Research*, **2** [2], 153 (1930).—A description is given of an experiment which is thought to be suggestive of processes affecting metamorphic changes in the earth's crust. Two bricks were fired side by side. One was composed of low lime Austrian dead-burned magnesite and the other of dolomitic magnesite and mill scale, mainly Fe_3O_4. Chemical analyses of each were tabulated. The temperatures were raised in steps of 30°C per hr. to 1390° and thereafter gradually in $12^1/_2$ hrs. to 1430°C. The total firing time was 60 hrs. While the first brick remained unchanged in shape, the one containing larger amounts of lime and iron oxide had bent over to one side until the upper edges just rested against its neighbor. Furthermore, the first brick for a distance of about one inch in every direction from the line of contact with the second brick exhibited a marked change of character, being here partially vitrified and of a reddish color, and this area was surrounded by a darkened zone extending irregularly into the body of the brick. Chemical analyses of portions removed from changed and normal areas are tabulated. These indicate that at some stage of the firing, lime and iron oxide had been actually transferred from one brick to the other and that certain other chemical changes had occurred in the first brick. It is emphasized that these phenomena had taken place between two solid bodies. Surface tension and the development of solid solutions may be among the obscure factors affecting these phenomena, the possible cause of which are discussed. W.L.

Diatomite. ANON. *Brit. Clayworker*, **39** [459], 149–53 (1930).—A summary of a report on "Diatomaceous Earth" issued by the Imperial Institute, 1928. The current article deals primarily with the formation, identity, and uses of the material. R.A.H.

Demand for sodium sulphate. ANON. *Chem. Met. Eng.*, **37** [7], 403 (1930).—As a by-product in the manufacture of HCl and HNO_3 only small quantities of Na_2SO_4 are being made, yet the demand for it is constantly increasing. A new Canadian plant to be erected is expected to supply 36,000 T. of Na_2SO_4 in its first year of operation from natural deposits. Burkeite, composed of Na_2SO_4, Na_2CO_3, and water, now discarded in large quantities in California, is a potential source. G.R.S.

Nature of dolomite and carbonates of bivalent metals. A. FERRARI. *Giorn. chim. ind. applicata*, **11** [12], 540 (1929).—The problem of the nature and origin of dolomite is discussed. F. explains his researches on the specific gravity and corrosion figures, and his attempts to obtain dolomite synthetically. His experiments demonstrated clearly that dolomite is a solid solution of calcium carbonate and magnesium carbonate. The

characteristics observed in the study of the rhomboid carbonates of bivalent metals are mentioned. M.V.K.

Water-free aluminium alums. N. SCHISCHKIN. *Z. anorg. allgem. Chem.*, **189** [2], 289–96 (1930).—A method is described for the preparation of sodium, potassium, and ammonium alums in which concentrated sulphuric acid is allowed to react with the sulphates of aluminium and the alkali metal at temperatures of 160 to 200 °C. Some of the properties of these alums are given. L.T.B.

Chemical composition of colloidal material isolated from the horizons of soil profiles. I. A. DENISON. *Chem. News*, **141** [3663], 404–405 (1930).—Composition of colloid material only in the upper part of the soil horizons has been determined. That of the lower part of the profile to the decomposing rock is important also, showing the changes resulting from leaching and aging. A diameter of 1 micron was taken as the upper limit of colloidal particles. Details of the process of separation of the colloidal material are given. Analyses are made by fusion by the Hillebrand method. In some profiles the colloids vary widely, while in others they are fairly constant. Constituents showing variations are generally SiO_2, Al_2O_3, Fe_2O_3, organic matter, and combined water. Molecular ratios of SiO_2 to $Al_2O_3 + Fe_2O_3$ show, in the case of colloids, from several profiles a regular decrease with depth indicating that extent of weathering is not the chief factor tending to reduce this ratio. The relatively low silica-sesquioxide ratios are attributed to the presence of free hydrated alumina in the colloidal material of the lower horizons. The relatively high percentages of Al_2O_3 and combined water in disintegrated but apparently undecomposed parent rock and the low p_H values of this material indicate that some of the minerals composing this material have undergone extensive alteration. G.R.S.

High and low silicic acids of definite composition. I. P. A. THIESSEN AND O. KOERNER. *Z. anorg. allgem. Chem.*, **189** [2], 168–73 (1930); *Sprechsaal*, **63** [30], 564 (1930).—By slow hydrolysis of ortho-silicic-acid-ethyl-ester in a large excess of water at room temperatures (18 to 20 °C), pure silicic acid hydrates were obtained and *p-x* diagrams were made on these preparations at 11 °C. They showed well-defined breaks corresponding to the following compositions: $SiO_2 \cdot 2H_2O$, $2SiO_2 \cdot 3H_2O$, $SiO_2 \cdot 1H_2O$, and $2SiO_2 \cdot 5H_2O$. The last compound may be considered as the di-hydrate of pyrosilicic acid. In the isothermal decomposition of the orthosilicic acid to metasilicic acid to the anhydrous silica there is formed the hydrate $2SiO_2 \cdot 1H_2O$. There are no breaks in this decomposition showing the formation of polysilicic acids. L.T.B.

Silicic acids of definite composition. (Isolation, p-t and t-x diagrams.) II. P. A. THIESSEN AND O. KOERNER. *Z. anorg. allgem. Chem.*, **189** [2], 174–82 (1930); *Sprechsaal*, **63** [30], 564 (1930).—The experimental method for preparing the individual silicic acids is given; *p-t* curves were then made on these preparations. These *p-t* curves were not always reversible, especially at the higher temperatures, due to the breakdown of the silicic acid hydrates. There is, however, a reversible region of the curves at about room temperatures (17 to 22 °C), which shows an appreciable stability of the hydrates at these temperatures so that they may be studied conveniently. The *t-x* curves were also made and, in agreement with the *p-x* diagrams, showed the existence of these hydrates: $2SiO_2 \cdot 5H_2O$, $SiO_2 \cdot 2H_2O$, $2SiO_2 \cdot 3H_2O$, $SiO_2 \cdot 1H_2O$, and $2SiO_2 \cdot 1H_2O$. L.T.B.

Physical chemistry of potash-bearing silicates. ANON. *Queensland Govt. Mining Jour.*, **31** [6], 248 (1930); for abstract see *Ceram. Abs.*, **9** [6], 470 (1930). E.P.R.

Oxidation products of titanium in the silicates. EMIL DITTLER. *Sitzungsb. Akad. Wiss. Wien*, Abt. I, **138**, 371–411 (1929); for abstract see *Ceram. Abs.*, **9** [6], 474 (1930). (*C.A.*)

Mississippi's new mineral wealth. ANON. *Mfrs. Rec.*, **95** [5], 36 (1930).—With the natural gas furnishing cheap and dependable fuel, the clay industry looms as a very

substantial industry for future development. Some Miss. sands are adapted to the manufacture of glass, and the generous deposits of fullers' earth indicate some of the mineral wealth of Miss., which no doubt will be utilized in the future. E.P.R.

Nonmetallic minerals in Illinois industry. ANON. *Pit and Quarry*, **20** [8], 27–30 (1930).—The mineral resources of Ill. consist of coal, clay, oil and gas, limestone, cement-making materials, silica sand, sand and gravel, molding sand, fluorspar, tripoli, fullers' earth, peat, and minor amounts of lead and zinc. During the five-year period, 1922 to 1927, the value of the total production averaged $239,094,642 per year, giving Ill. a rank ahead of 41 other states in the Union. Of this amount approximately 63% was from coal, 11% from clay and clay products, 5% from oil and gas, 5% from sand and gravel, 3½% from limestone, and 12½% from other products. E.P.R.

Clay resources and ceramic development of Oklahoma. L. F. SHEERAR. *Mfrs. Rec.*, **95** [5], 51 (1930); for abstract see *Ceram. Abs.*, **9** [3], 183 (1930). E.P.R.

Manchurian china clay deposits. DIE BRÜCKE. *Pottery Gaz.*, **55** [638], 1288 (1930).—There are many china clay deposits of good industrial quality in Manchuria. An important reserve is that of Wusuhui, near Fusien, estimated by Japanese geologists to amount to 28,125,000 metric tons. The Japanese are exploiting this deposit, the product being used chiefly by the Japanese porcelain factories in Tairen. E.J.V.

Production of nonmetallic minerals in Canada. ANON. *Pit and Quarry*, **20** [8], 78 (1930); for abstract see *Ceram. Abs.*, **9** [3], 228 (1930). E.P.R.

Canada's mineral production. ANON. *Chem. News*, **141** [3661], 375 (1930).—In the discussion of the table it is shown that the output of coal, feldspar, natural gas, and zinc has gained in Jan., 1930 over Dec., 1929. G.R.S.

Development of mineral deposits in Russia. ANON. *Rev. mat. constr. trav. pub.*, pp. 316–17 (Aug., 1929); *Pit and Quarry*, **19** [2], 116 (1929).—Russia is now the principal source of the kaolin used in Poland, formerly supplied by England. A plant will be built near Murmansk for the treatment of apatite so as to stimulate the Russian exports of feldspar. A clay called "floridine," used principally in the oil industry, has heretofore been imported largely from the U.S., but deposits of floridine have been discovered in the republic of Georgia and a plant for grinding this clay is now being built at Koutais. New deposits of amianthus asbestos have been found, and it has been determined that the deposits of this mineral in the Caucasus region and Siberia could be put into exploitation on short notice for the production of 2000 to 3000 T. a year. E.P.R.

Geology of the fire clays of southern Saskatchewan. G. M. HUTT. *Jour. Amer. Ceram. Soc.*, **13** [3], 174–81 (1930); *Clay Prod. News*, **3** [7], 3–8; [8], 3–5 (1930).—The fire clays belong to the Whitemud formation, which is of Lance (late Cretaceous) Age. The formation is usually represented by three zones: at the bottom a maximum of 45 ft. of partly kaolinized feldspathic sands, a thin carbonaceous zone in the middle, and at the top a maximum of 35 ft. of plastic clays intercalated with fine sands and silts. Increase of the sands in coarseness eastward implies an eastern source of the sediments, possibly the pre-Cambrian of northern Canada. The plastic clays are probably derived from the feldspathic sands and are due to a reworking of the sands and their kaolinization in Whitemud time. The strata are practically flat lying, with a regional eastward, and possibly northward, dip. The eastern clays, having fusions as high as cone 33, are more refractory than the western ones.

Barite in Sardinia. ANON. *Rock Prod.*, **33** [16], 59 (1930).—A deposit of barite has been found in Sarala, Sardinia, showing 93.32% $BaSO_4$. W.W.M.

Potash discovery reported in Spain. ANON. *Christian Sci. Mon.*, **22** [215], 8 (1930).—A field of potash 9 m. deep has been found at a depth of 80 m. near Pamplona, in Navarra. The zone is believed to be 50 to 60 kilometers wide, extending from Pam-

plona to the River Aragon. If this is true, Spain will become the biggest producer of potash in the world. E.J.V.

Feldspar lead held by N. Carolina. H. J. BRYSON. *Christian Sci. Mon.*, **22** [208], 5 (1930).—Production of feldspar in 1929 in North Carolina amounted to 103,273 long T., valued at $598,938. Production of feldspar in the entire country in 1929 amounted to 197,699 T., valued at $1,276,640, so that N. C. produced more than half in quantity and not quite half in value. See also *Ceram. Abs.*, **9** [6], 480 (1930). E.J.V.

Fluorspar industry in 1929. HUBERT W. DAVIS. *Blast Fur. Steel Plant*, **18** [8], 1362 (1930).—The fluorspar industry did a bigger volume of business in 1929 than in 1928. The shipments of fluorspar from mines in the U.S. in 1929, amounting to 146,439 short T., consisted of 127,054 T. of gravel fluorspar, 8325 T. of lump fluorspar, and 11,060 T. of ground fluorspar. E.J.V.

Magnesite in 1929. ANON. *Blast Fur. Steel Plant*, **18** [8], 1355 (1930).—The total quantity of crude magnesite mined in the U.S. in 1929 was 187,660 short T., with an approximate value of $1,500,000. This represents the largest quantity mined since 1920 and was an increase of 47.5% over that reported in 1928. Four operators in California are working mines in four counties. E.J.V.

BOOKS AND BULLETINS

Deposition of the Sedimentary Rocks. J. E. MARR. Cambridge Univ. Press, London, 1930. Price 7s 6d. A general account is given of the conditions which have controlled the distribution of the various kinds of sedimentary deposits in time and space. The features relating to their organic contents are also treated. H.H.S.

Structure and Surface; A Book of Field Geology. C. BARRINGTON BROWN AND F. DEBENHAM. Edward Arnold & Co., London, 1929. Longmans, Green, & Co., New York. 168 pp., illustrated, diagrams. $4.20. Reviewed in *Mining and Met.*, **11** [284], 22 (1930).—This is a textbook on the recognition of geological structures in the field intended for beginners. Practical instructions on field equipment, mapping, and the construction of block diagrams are given. Block diagrams, or stereograms, are used to illustrate the work, all being taken from actual structures. E.J.V.

Guide to the Study of Nonmetallic Mineral Products, Except Building Stones. W. S. BAYLEY. Henry Holt & Co., N. Y. 1930. 530 pp., illustrated, maps, tables. Reviewed in *Mining and Met.*, **11** [284], 20 (1930).—This is a brief course in the origin and occurrence of the more important nonmetallic minerals that are used in the industries. The work aims to give the student a general knowledge of these substances and their uses and economic importance, with reference to authoritative sources for further information. E.J.V.

Geophysical Abstracts. XI. FREDERICK W. LEE. Bur. Mines, *Information Circ.*, No. 6273, 27 pp. (1930).—A résumé of recent publications on the theory and application of geophysical methods of prospecting. For Part X see *Ceram. Abs.*, **9** [6], 467 (1930); Part XII, *ibid.* [7], 575 (1930). R.A.H.

Geophysical Abstracts. XIV. FREDERICK W. LEE. Bur. Mines, *Information Circ.*, No. 6324, 24 pp. (1930).—L outlines recently published articles and books concerned with geophysical methods of prospecting. For Part XIII see *Ceram. Abs.*, **9** [9], 783 (1930). R.A.H.

Canadian report on ore dressing. ANON. Dept. of Mines, Mines Branch, Ottawa, *Pamphlet*, No. 711; *Rock Prod.*, **33** [15], 71 (1930).—A report of tests made during 1928, on both metallic and nonmetallic problems, including washing of china clays is printed in this pamphlet. C. S. Parsons, R. K. Carnochan, and R. A. Rogers wrote the chapters on nonmetallics. W.W.M.

Chemistry and Physics

Etymology of the words "ceramic" and "clay." V. D. TALWALKAR. *Jour. Indian Ceram. Soc.*, **2**, 48–55 (1930).—Etymology of the word "ceramic" by William A. Oldfather is criticized (*Jour. Amer. Ceram. Soc.*, **3**, 537 (1920)). According to Oldfather the word *Keramos* is used of articles made exclusively or ordinarily out of clay by the process of firing. Sun-dried brick would not be called *Keramos* or any other relative word. This emphasizes the process not the material as the most characteristic feature. Some possible derivations are mentioned which either include the process of firing or simply suggest the plastic raw materials for earthenware. A.A.

Analytical methods in phase-rule problems. G. W. MOREY. *Jour. Phys. Chem.*, **34** [8], 1745–50 (1930).—A general analytical method especially adapted to phase-rule work has been developed. A problem which frequently arises in the study of 3-component systems is that of the locus of points fulfilling a desired relation. The simplified equation $Ax + By = C$ is employed. Using x and y as expressed variables, Z is determined by the relation $x + y + z = 1$. Illustrations of the use of this equation are given. In a 4-component system an equation of the type $Ax + By + Cz = D$ is used. By means of the determinant notation, calculations are given to illustrate the use of the equation. G.R.S.

Ternary system K_2O–CaO–SiO_2. G. W. MOREY, F. C. KRACEK, AND N. L. BOWEN. *Jour. Soc. Glass Tech.*, **14** [54], 149–87 (1930).—Compositions studied give the melting relations in that portion of the ternary system from $K_2O{\cdot}SiO_2$ to $K_2O{\cdot}CaO{\cdot}SiO_2$ and all more siliceous mixtures. Less siliceous mixtures are difficult to study because of (1) the volatility of K_2O, (2) hygroscopic nature, (3) difficulty of expelling CO_2, and (4) high temperatures involved. Densities and optical properties of glasses which can be readily produced have been determined and will soon be published. In the preparation of glasses the carefully mixed ingredients were heated for some time without much sintering to prevent loss by heavy frothing. The glasses were powdered and sieved (66-mesh) and remelted, the process being repeated till no inhomogeneity could be detected. The composition of most of the glasses was established by careful control throughout the melting process. The possible sources of error by this method are discussed. It is felt that the compositions made by controlled synthesis are better known than those made by chemical analysis. The equilibrium diagram is divided into 17 fields representing the composition regions of divariant equilibria within which the various compounds separate as primary phases. Three refer to the three forms of SiO_2; one to the region of immiscibility; two to the two forms of $CaO{\cdot}SiO_2$; one to $2CaO{\cdot}SiO_2$; three to the known compounds $K_2O{\cdot}SiO_2$, $K_2O{\cdot}2SiO_2$, and $K_2O{\cdot}4SiO_2$; and the remaining seven to the various new compounds. These are (1) $K_2O{\cdot}CaO{\cdot}SiO_2$, (2) $2K_2O{\cdot}CaO{\cdot}3SiO_2$, (3) $K_2O{\cdot}3CaO{\cdot}6SiO_2$, (4) $4K_2O{\cdot}CaO{\cdot}10SiO_2$, (5) $2K_2O{\cdot}CaO{\cdot}6SiO_2$, (6) $K_2O{\cdot}2CaO{\cdot}6iSO_2$, and (7) $K_2O{\cdot}2CaO{\cdot}9SiO_2$. Compositions and melting temperatures, critical quenches, properties of crystalline phases, and invariant points are given in 4 tables. The K_2O–CaO–SiO_2 system is characterized by the formation of more compounds than the Na_2O–CaO–SiO_2 system; by the tendency of these compounds to dissociate on melting; by the greater viscosity of the melts at the liquidus over a larger proportion of the diagram; and by the great sluggishness in portions of the diagram. The application to glass technology is briefly discussed. G.R.S.

Vapor pressure of silicon tetrafluoride. W. I. PATNODE AND J. PAPISH. *Jour. Phys. Chem.*, **34** [7], 1494–96 (1930).—Silicon tetrafluoride was prepared by treating a mixture of calcium fluoride and an excess of silica with sulphuric acid. The evolved gas was carefully dried and purified by repeated fractional distillation. Vapor pressure measurements were made. To determine the triple point, the logarithms of the pressures were plotted against the reciprocals of the absolute temperatures. The equa-

tions of the curves calculated from these data are (1) for the solid-vapor curve $\log p = -1346.2 \times \frac{1}{T} + 10.48$, and (2) for the liquid-vapor curve, $\log p = -975.0 \times \frac{1}{T} + 8.453$. The boiling point at one atmosphere is −95.7°C. G.R.S.

System sodium oxide-silica. F. C. KRACEK. *Jour. Phys. Chem.*, **34** [7], 1581–98 (1930).—The system Na_2O–SiO_2 contains three binary compounds, the orthosilicate ($2Na_2O \cdot SiO_2$), the metasilicate ($Na_2O \cdot SiO_2$) and the disilicate ($Na_2O \cdot 2SiO_2$). The orthosilicate decomposes at 1120° ± 5° (in mixtures containing less than 40.7% SiO_2) before its melting point is reached. A new value, 1089° ± 0.5°, is given for the melting point of the metasilicate, and Morey and Bowen's value for the melting point of the disilicate, 874° ± 1°, is confirmed. The ortho-metasilicate eutectic is at 43.1% SiO_2 and 1022° and the meta-disilicate eutectic is at 62.1% SiO_2 and 846°. The stable eutectic between the disilicate and quartz is located at 73.9% SiO_2 and 793°, and the metastable one between the disilicate and tridymite at 74.6% SiO_2 and 782°. Sodium disilicate has a reversible inversion at 678°. At temperatures above 706°, it takes up excess Na_2O; above 768°, excess SiO_2 into solid solution. The problems connected with the investigation of the orthosilicate region are discussed in detail. G.R.S.

Structure of tricalcium aluminate. F. A. STEELE AND W. P. DAVEY. *Z. Krist.*, **73**, 17–30 (1930); for abstract see *Ceram. Abs.*, **9** [5], 331 (1930). G.R.S.

Structure of thortveitite. W. H. ZACHARIASEN. *Z. Krist.*, **73** [1], 1–6 (1930).—The structure of thortveitite, $Sc_2Si_2O_7$, was determined by oscillation photographs and absolute intensity measurements. The monoclinic cell containing 2 molecules has dimensions $a = 6.56$ Å, $b = 8.58$Å, $c = 4.74$ Å, $\beta = 103°8'$. The space group is C_{2h}^3. The atoms have the following positions in the cell: $4Sc(0u^1/_2)$ $u = 108°$; $4Si(u0v)$ $u = 80°$, $v = -23°$; $2O(000)$; $4O(u0v)$ $u = 145°$, $v = 84°$; $8O(xyz)$ $x = 90°$, $y = 54°$, $z = 97°$. Si is tetrahedrally surrounded by 4 O at a distance 1.62 Å. The SiO_4-tetrahedra are connected together in pairs by a common corner so as to form Si_2O_7 groups. Sc is surrounded by 6 O at a distance 2.18 Å. The structure satisfies the empirical rules of silicate structures. G.R.S.

X-ray studies on the systems Fe_2O_3-Cr_2O_3 and Fe_2O_3-Mn_2O_3. P. ERIK WRETBLAD. *Z. anorg. allgem. Chem.*, **189** [4], 329–36 (1930).—X-ray studies on the system Fe_2O_3–Cr_2O_3 showed that the rhombohedral Fe_2O_3 and Cr_2O_3 form a continuous series of solid solutions. The edge of the unit cube varies directly as the composition. Fe_2O_3 is somewhat soluble in the cubic Mn_2O_3 and it seems as if Mn_2O_3 is slightly soluble in Fe_2O_3. No changes in the lattice constants in this system were noticeable. No binary compounds were detected. L.T.B.

Crystal structure of titanite. W. H. ZACHARIASEN. *Z. Krist.*, **73** [1], 7–16 (1930).—The structure of titanite, $CaTiSiO_5$, was determined by means of absolute intensity measurements, Laue photographs, and oscillation photographs. The monoclinic unit cell containing 4 mols. has the dimensions: $a = 6.55 \pm 0.01$ Å, $b = 8.70 \pm 0.01$ Å, $c = 7.43 \pm 0.01$ Å, $\beta = 119°43'$. The space group is C_{2h}^6 and the atomic positions are $4Ca\ (0\ u_1\ 0)\ u_1 = -30°$; $4Ti\ (\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4})$; $4Si\ (0\ u_2\ 0)\ u_2 = -155°$; $4O_I\ (0\ u_3\ 0)\ u_3 = 67.5°$; $8O_{II}\ (x_1\ y_1\ z_1)\ x_1 = 90°$, $y_1 = 166°$, $z_1 = 54°$; $8O_{III}\ (x_2\ y_2\ z_2)\ x_2 = -10°$, $y_2 = -166°$, $z_2 = 54°$. Si is surrounded tetrahedrally by 4 oxygen atoms at a distance 1.64 Å. Ti is surrounded by 6 oxygen atoms in an octahedron, the Ti-O distance being 1.96 Å. Ca is surrounded by 7 oxygen atoms, the distance Ca-O being 2.44 Å. G.R.S.

Recent work on mass spectra. F. W. ASTON. *Engineering*, **128**, 385 (1929).—The improvements effected in recent work in the mass spectrograph are described. Oxygen is shown to be triple with atoms having weights 16, 17, and 18. Since all the isotopes are reckoned on a basis of oxygen = 16, they are all slightly too low. A.A.

Micro-determination of calcium. A. ASTRUC, M. MOUSSERON, AND N. BOUISSOU. *Compt. rend.*, **190**, 376–77 (1930); *Analyst*, **55**, 297 (1930).—Ca is precipitated as tungstate and changed to yellow WO_3 by HCl and boiling. This is dissolved in KOH, neutralized with HCl in presence of litmus and reduced with $TiCl_3$. The blue pentavalent tungsten compound formed is compared with a standard in a colorimeter. The method is accurate to 0.02 mg. Ca, Fe, P, and organic matter do not interfere. H.I.

X-ray crystal analysis in engineering. V. E. PULLIN. *Engineer*, **150** [3886], 2–4 (1930).—The discovery and development of the science of X-rays are discussed briefly. The different kinds of crystals are classified into thirty-two classes and those important to the engineer are given and explained by diagrams. The fundamental principle of the methods of Laue and of Bragg is given. The chief things of importance obtained from crystal analysis are (1) size of crystals, (2) manner in which crystal units are oriented, (3) effect on crystal lattice of adding small quantities of foreign materials, such as carbon in iron to produce steel, (4) effect of cold working and annealing on crystal units, and (5) how strain in metal may be detected by X-ray. The single-crystal method, the powder method of Hull and Debye and Scherrer, and the pinhole method are described briefly. Characteristic diagrams obtained by the pinhole method, showing the effect of grain size, orientation of grains, effect of heat, strains, rolling, annealing, and cold working upon the pattern obtained are explained. Questions concerned with carbide in steel, crystal structure of alloys generally and particularly the brasses; the effect of the alloy elements in modern complicated steels, the differences between good and bad transformer iron, and the structure and properties of electro-deposited metals, and many others are all suitable subjects for X-ray spectra investigations. Patterns obtained from electro-deposited nickel by the reflection method are given and explained. An application of X-ray analysis which has not received the experimental attention merited is chemical analysis by X-rays. The purpose of this paper was to show the engineer that X-rays offer definite promise in practical engineering problems. H.W.A.

Correction factors in the photographic measurement of X-ray intensities in crystal analysis. E. G. COX AND W. F. B. SHAW. *Proc. Roy. Soc.*, **A127** [A804], 71–88 (1930).—Possible sources of error in the measurement of the integrated intensities of X-ray reflections by crystals from photographic records are discussed, and correction factors are developed for their elimination. These are (1) a factor dependent upon the geometrical arrangements of the crystal and the X-ray spectrometer, and (2) a correction introduced by obliquity of incidence of the reflected X-rays on the photographic film. The ordinary polarization factor $\frac{1}{2}(1 + \cos^2 2\theta)$ is examined critically and found to be valid in practice. Experimental figures are quoted illustrating the use of the correction factors. G.R.S.

Michelson. An appreciation of America's foremost optical physicist. W. H. CREW. *Sci. Amer.*, **142** [5], 376–78 (1930).—A brief sketch is given of the scientific achievements of Professor A. A. Michelson. G.R.S.

Determination of fluorine as calcium fluoride. E. CARRIERE AND JANSSENS. *Compt. rend.*, **190**, 1127 (1930); *Sprechsaal*, **63** [30], 565 (1930).—The precipitation of fluorine from a solution in which it is present as an alkali fluoride with alkali chlorides, is accomplished by adding $CaCl_2$ to a boiling solution of ammoniac in a platinum dish. The sediment deposits quickly and is washed with boiling ammoniacal water by decanting until the Cl reaction ceases. The results obtained in such a way show an average error of 0.6% while in using a porcelain dish the average error amounted to 6%. The aluminium and iron salts present are precipitated by ammoniac in a platinum dish, filtered through a platinum funnel, and washed with boiling ammoniacal water until the disappearance of the F-reaction. It can be filtered also through a paraffined glass funnel, but, in this case the filtration and washing must be done while cold. The filtrate

is then concentrated, the traces of the $Al(OH)_3$ filtered, and the fluorine precipitated as described above. M.V.K.

Estimation of chromium in chromite. K. BRADDOCK-ROGERS. *Chem. News*, **141** [3657], 305–307 (1930).—A discussion of previous methods is followed by a detailed description of B.'s method of decomposing the mineral with sodium peroxide, and subsequent estimation of Cr_2O_3 by means of either (1) $KMnO_4$ or (2) electrometric separation. Especial emphasis is placed on decomposition of the excess of sodium peroxide by boiling for a successful analysis. G.R.S.

Electrometric titration of phosphoric acid and superphosphate solutions using the antimony electrode as indicator. J. C. VOGEL. *Chem. and Ind.*, **49** [28], 297–300 (1930).—The apparatus used consisted of two sticks of cast antimony metal which had been dipped into concentrated HNO_3 and then washed. One of these was dipped into a beaker containing the solution to be titrated and the other into a beaker containing 0.1*N*HCl, and acted as the fixed single-potential half cell of the concentration cell. The content of these two beakers was electrically connected by means of a siphon filled with a 3% agar-agar jelly made up with a saturated KCl solution. The e.m.f. between the two antimony electrodes of this concentration cell was measured on a potentiometer by the compensation method, the point of balance being determined by means of a capillary electrometer. The method is rapid and does not require complicated apparatus. G.R.S.

Determination of alumina. S. A. POGODIN. *Mineral-Rohstoffe und Nichteisenmetalle*, **4**, 54–56 (1929); *Chem. Zentr.*, **101** [1], 713 (1930); *Stahl Eisen*, **50** [29], 1034 (1930).—One gram of the investigated material is heated in a porcelain container in an electric kiln. First, hydrogen gas is introduced to remove the air and then the aluminum is volatilized at 250° by passing over hydrogen chloride. The reaction is completed in 15 or 20 minutes. The nonvolatile residue contains the total alumina content. For the determination of this alumina the residue is fused with potassium pyrosulphate, dissolved in acidified water, and the copper is liberated by hydrogen sulphide. Iron oxide and aluminium oxide are first determined together in the usual manner, and then, after determination of iron, aluminium oxide is ascertained from the difference. In a pure aluminum metal about 0.1% Al_2O_3 was found and in aluminum alloys, 0.06%. M.V.K.

Determination of alumina. W. MIEHR, P. KOCH, AND J. KRATZERT. *Z. angew. Chem.*, **43**, 250–54 (1930); *Stahl Eisen*, **50** [29], 1032–33 (1930).—For the determination of alumina the ammonia process is used to precipitate aluminum as hydroxide. A sediment of uncertain water content is obtained which is converted into oxide by heating to redness; it is then weighed. It is known that complete dehydration of aluminium hydroxide requires a temperature of at least 1200°, but the temperature usually obtainable in laboratories is about 1000 to 1100°. The authors undertook to determine whether the differences in the quantities of alumina found by analysis in different laboratories are influenced by different temperatures of heating to redness. An "Effix" muffle furnace was used for the tests. Ammonium chloride served as initial substance. The sediment precipitated with ammonia in a watery solution was heated to redness at different temperatures between 900° and 1350° for one hour. The material heated to redness at 1350° was considered to be pure aluminium oxide. The experiment showed that the aluminium oxide must be heated to redness to constant weight at at least 1200°, or better, 1300°. An ordinary illuminating gas air blast does not suffice. The oxide heated to redness can increase in weight at most about 0.1% in a calcium chloride exsiccator. It can be only slightly colored by alyzarine. If these conditions are not maintained the results are at least 0.8% too high and fluctuate about 3% and more, according to conditions of heating to redness and cooling. In the determination of alumina as

aluminium phosphate, care must be taken that the phosphate heated to redness contains up to 1% water before the blast. Only by the use of a good blast can this error be lowered to about 0.5%, when the aluminium phosphate remains not longer than $^1/_2$ or at most 1 hr. in the exsiccator before weighing. It is much better to heat the aluminium phosphate to redness to constant weight at 1200 to 1300°. At 1300°, it is unnecessary to avoid a long duration of heating to redness as otherwise losses of phosphorous pentoxide can occur; the same happens at higher temperatures of heating to redness. The experiments showed that, in general, the temperature of a good blast suffices to dehydrate the precipitated silicic acid. M.V.K.

Perchloric acid method of silica analysis: advantages over double evaporation. WALLACE K. GIBSON. *Rock Prod.*, **33** [15], 70–71 (1930).—G. cites sources of error in the double-evaporation method of silica analysis and gives the procedures for analyses of cement and limestone or raw mix by the perchloric-acid method. Comparative data are given on the analysis of several clinkers and cements by the single-evaporation and double-evaporation methods, using HCl and the perchloric-acid method. W.W.M.

Determination and separation of zirconium and beryllium. OTTO RUFF AND E. STEPHAN. *Z. anorg. allgem. Chem.*, **185,** 217–20 (1929); *Sprechsaal*, **63** [30], 565 (1930).—The following method was used for the separation of Zr and Be: ZrO_2 and BeO are decomposed by $NaHSO_4$ in a platinum crucible; the fusion is dissolved in a 2% solution H_2SO_4, the dissolved precipitate is precipitated by introducing H_2S in the warm solution, filtered off, and washed. About 100 cc. of filtrate (1 g. ZrO_2), is mixed with 20 cc. of a 10% ammonium phosphate solution. The gelatinous zirconium phosphate is deposited in a water bath, then filtered through a Gooch crucible, washed 4 or 5 times with a warm 2% H_2SO_4 solution and heated to redness and weighed (the Gooch crucible loses in weight and must be weighed again). The solubility of ZrP_2O_7 amounts to about 3 to 4 mg./liter. The filtrate of zirconium phosphate is mixed drop by drop with ammoniac until the liquid smells of ammoniac and the gelatinous precipitate produced ceases to dissolve. It is left in the water bath until the precipitate becomes finely crystalline and settles to the bottom; it is filtered in a Gooch crucible, washed 4 or 5 times with a 1% solution of warm ammoniac, dried, and heated to redness. The precipitate contains more P_2O_5 than in the corresponding formula $Be_2P_2O_7$: the reducing factor for $Be_2P_2O_7/2BeO$ is theoretically 0.260 and from the analyses of the authors the factor was found to be 0.255 ± 0.002. M.V.K.

Determination of true sodium content of calcium carbonate intended for use in J. Lawrence Smith method for alkalis. EARLE R. COLEY. *Ind. Eng. Chem., Anal. Ed.*, **1,** 191 (1929); *Sprechsaal*, **63** [30], 565 (1930).—The usual method for testing $CaCO_3$ on its alkali content, *i.e.*, by boiling 4 g. of $CaCO_3$ in 50 cc. water, filtering, boiling to dryness, heating to redness, and weighing the residue, is inexact because it is impossible to wash the alkali salts completely away from the insoluble residue. The following method is therefore suggested for the determination of the alkalis contained in $CaCO_3$: 2 g. $CaCO_3$ are dissolved in a 150-cc. Erlenmeyer flask in dilute HCl (1:1), and boiled almost to dryness. The residue is dissolved in 2 to 3 cc. H_2O. Then 50 cc. of magnesium uranyl acetate solution are added and mixed well; the bottom of the flask is immersed in a large cup containing water at 25°C and the solution stirred for 45 min. The sediment is put in a weighed Gooch crucible and washed 4 or 5 times with 5 cc. of a washing liquid. The crucible containing the residue is dried at a temperature of 100 to 105°C for 30 min. The weight of the residue multiplied by 0.0153 gives the Na_2O content of the sample. Preparation of the reagents follows: (1) 85 g. of crystallized uranyl acetate and 60 g. of glacial acetic acid. Distilled water is added up to 1000 cc. (2) 500 g. crystallized magnesium acetate and 60 g. of glacial acetic acid to which distilled water is added to 1000 cc. (1) and (2) are heated to 70°C to complete dissolving; both

solutions are then well mixed, cooled to 20°C, and kept at this temperature for 1 to 2 hrs., until the small surplus of salt is crystallized, and then filtered through a dry filter. The solution is stable. In case of a reaction of the salt with the alkali of the vessel in which it is kept, a small sediment originates which must be filtered off before using the solution. For the preparation of the washing liquid, the 2 cc. of a 1 to 2% NaCl solution are precipitated with 50 cc. of the above-mentioned reagent; the resulting sediment of sodium uranyl magnesium triacetate is shaken at short intervals for 1 hr. with 95% alcohol. The sediment obtained is washed with the filtrate. It must be noticed when performing this test, that when evaporating the sample dissolved in HCl it must be completely removed as precipitation is incomplete in the presence of HCl, but the evaporation must not be made at too high temperatures as a disintegration of $CaCl_2$ can occur and in this case an impure solution will be obtained. The last part of the evaporation must be made therefore in a water tub. This method is distinguished from the extraction method by its speed and exactness as it is shown by a series of examples. See also *Ceram. Abs.*, **9** [9], 787 (1930). M.V.K.

Oxygen analysis in the boiler room. M. E. FRITZE. *Power*, **72** [4], 136–39 (1930).—Protection of boilers from pitting or corrosion requires, first of all, a feedwater free from oxygen. De-aerating equipment may lose much of its effectiveness if the thoroughness of de-aeration is not constantly checked. The Winkler method of oxygen analysis is described. Preparation and standardization of the necessary solutions is given. H.W.A.

Isotopes. ANON. *Engineering*, **129** [3355], 461 (1930). A.A.

Possibility of representation of a function of four variables, with practical application to the four-component diagram. FRITZ HÖNIG VON HÖNIGSBERG. *Z. anorg. allgem. Chem.*, **189** [2], 215–33 (1930).—A new method is described by which colors are utilized in the representation of 2-, 3-, and 4-component systems. L.T.B.

Scientific method in industry. HENRI LE CHATELIER. *Rev. belge ind. verrières*, **1**, 101–102 (1930); see also *Ceram. Abs.*, **9** [9], 795 (1930). A.J.M.

Further study of influence of proximity of a solid wall on consistency of viscous and plastic materials. G. W. SCOTT BLAIR. *Jour. Phys. Chem.*, **34** [7], 1505–1508 (1930).—The case of a material streaming through a tube and having a layer showing modified consistency constants in the immediate neighborhood of the wall of the tube is discussed. The empirical "correction" constants proposed in the previous paper are expressed in terms of the consistency constants (modified and otherwise) of the material. G.R.S.

Conversion of combined metric units into British units. I. EMIL KLAPPER. *Engineering*, **128**, 490 (1929).—A table for the conversion of combined metric units into British or American units is given. Usual application of the units is also mentioned. A.A.

Conversion of combined metric units into British units. ANON. *Engineering*, **129** [3338], 20 (1930).—A revised comprehensive table of factors for converting quantities expressed in combined metric units into the corresponding quantities expressed in British or American units is given. A.A.

Relationships between Rockwell and Brinell numbers. S. N. PETRENKO. Bur. Stand., *Jour. Research*, **5** [1], 19–50 (1930).—Comparative Rockwell and Brinell tests were made on a variety of ferrous and nonferrous metals. Relationships between Brinell and Rockwell numbers, based on certain simplifying assumptions, are Brinell number $= \frac{\text{constant}}{\text{130-Rockwell ball number}}$; Brinell number $= \frac{\text{constant}}{(\text{100-Rockwell cone number})^2}$

These equations were used as guides in finding empirical formulas which fitted most closely the values determined experimentally. Of all the experimental values obtained

in this investigation, few differed by more than 10% from values obtained from these empirical equations. R.A.H.

Calculation of diversity factors. S. PROCHOROFF. *Electrotech. Z.*, **51**, 230–31 (1930).—Nomograms are given for determining the diversity factor of a network having a number of loads of different magnitudes and durations. M.A.B.

Reflection of hydrogen atoms from lithium fluoride. T. H. JOHNSON. *Jour. Frank. Inst.*, **210** [2], 135–52 (1930).—J. describes the phenomena associated with the reflection of a sharply-defined beam of hydrogen atoms from a crystal of LiF. Of primary interest is the fact that the atoms show interference effects in agreement with the wave-mechanics theory and plane-grating diffraction patterns are photographed. Evidence of the thermal agitation of the surface ions is obtained from the diffuse reflection which surrounds the specular beam. A description and illustrative sketch of the experimental arrangement is given. M.A.B.

Sunlight, natural and synthetic. C. E. GREIDER AND A. C. DOWNES. *Trans. Illum. Eng. Soc.*, **25**, 378–96 (1930).—Solar radiation energy curves were determined throughout ultra-violet, visible, and infra-red, by use of a quartz spectro-radiometer and thermopile with calibrated transmission screens. Comparative measurements were made for C arcs with Ce or rare earth salts. An investigation was also made of reflector design for use with these arcs. M.A.B.

Potash from polyhalite. ANON. *Chem. News*, **141** [3666], 43 (1930).—A description of the two processes which have been developed by the Bur. of Mines Expt. Sta. at Rutgers Univ. for the production of K_2SO_4 and a double salt of $MgSO_4$ and K_2SO_4 is given. Texas polyhalite is the raw material used. G.R.S.

Fusibility of aluminum and alpax. COURTY. *Compt. rend.; Giorn. chim. ind. applicata*, **12** [5], 266 (1930).—Tests were made on aluminum (99.8%) and on alpac (87% Al + 13% Si) at constant pressure in an apparatus with fusible valves. The variations in results did not exceed 4%. Under similar conditions the fusibility of alpax exceeded that of aluminum by 30% and has, therefore, a lower fusing temperature. M.V.K.

Colloidal nature and water content of clays. I. H. BERRIDGE. *Engineering*, **130** [3364], 5 (1930).—Information explaining the structure and behavior of clay in the raw state as affecting engineering and building operations is set forth. Some experiments done in this connection are described. **II.** *Ibid.*, **130** [3366], 61–63 (1930).—State of knowledge regarding the colloidal properties of clays and a series of experiments performed to throw additional light on the subject are set forth. A.A.

Effective slip practice. ANON. *Ceram. Ind.*, **15** [1], 74–80 (1930).—The properties of suspensions of clays, glazes, and enamels are discussed, including settling, flocculation, deflocculation, viscous flow, and plastic flow. The effect of various reagents on these properties and mobility and yield value are noted. The works on suspensions of Deane, Hall, Cook, Scripture, Bingham, Wilson and Hall, Shearer, Bleininger and Hornung, Cooke, and Harrison are cited. Papers of Shaw, Bowman, Lee, Schramm and Sherwood, Danielson, Thomson, Foster, Gerber, Fetterolf, and Spurrier are cited on glaze suspensions, their control, etc. A mobilometer suitable for determining the mobility and yield value of most glazes is mentioned. W.W.M.

Variation of viscosity of liquids with temperature. E. W. MADGE. *Jour. Phys. Chem.*, **34** [7], 1599–1606 (1930).—An equation is derived representing the variation of viscosity of a liquid with temperatures. It was tested for a number of liquids and comparison made of the observed and calculated values. The formula was found to hold for a number of other liquids both normal and associating over a wide range of temperatures. G.R.S.

Quick method for determining humidity in grog, half-porcelain pastes, and in

granulated blast-furnace slag. P. P. BUDNIKOFF. *Stahl Eisen*, **50** [29], 1033 (1930); for abstract see *Ceram. Abs.*, **9** [9], 789 (1930). M.V.K.

Study on drying of clay and clay mixtures. I. V. BODIN AND P. GAILLARD. *Brit. Clayworker*, **39** [459], 130–33 (1930); see *Ceram. Abs.*, **9** [6], 472 (1930). R.A.H.

Convenient method of determining the humidity of any gas. LESLIE B. BRAGG. *Gas Age-Rec.*, **66** [5], 153–56 (1930).—The psychrometric or wet- and dry-bulb method of determination of the moisture content of gases is sufficiently accurate for most plant test or control work. While the necessary data may thus be easily obtained, the calculation of the desired information from these data is tedious. Most humidity charts are based on air at normal barometric pressure. On the other hand, industrial gases have widely varying molecular weights and specific heats and the moisture data may be obtained at other than normal barometric pressure. As the ordinary humidity chart is of little use on this account, a set of charts designed for use in connection with any gas having a molecular weight of not over 40, under pressures up to 30-lbs. gage, is presented. The two fundamental equations which were used in the construction of the charts were: $H_w = \frac{p_w \times 18}{(P - p_w)\,M}$ and $H = H_w - [(c_p + 0.465H) \div r_w][t - t_w]$, where H is lbs. of water-vapor per lbs. of water-free gas or the humidity of the gas; P, total pressure in the apparatus in inches of mercury absolute; p_w, partial pressure exerted by water-vapor, in inches of mercury, at wet-bulb temperature; M, average molecular weight of the gas; H_w, humidity of the gas saturated at the wet-bulb temperature; c_p, average specific heat of the gas in B.t.u. per lb. per °F; r_w, latent heat of water at the wet-bulb temperature in B.t.u. per lb.; t, dry-bulb temperature in °F; t_w, wet-bulb temperature in °F. A typical problem using these charts is worked out. E.J.V.

BOOKS AND BULLETINS

Statistical Tables and Graphs. BRUCE D. MUDGETT. Houghton Mifflin Co., Boston, Mass., 1930. 194 pp. $1.75. Reviewed in *Mining and Met.*, **11** [284], 22 (1930).—This is an elementary textbook of statistical methods intended for those who expect to become business men, not statisticians. Emphasis is directed to those elementary statistical methods, the preparation of tables of figures and graphs, which are most used in business. The presentation is clear and refreshingly concise. E.J.V.

Physics and Chemistry of Surfaces. NEIL KENSINGTON ADAM. Clarendon Press, Oxford; Oxford University Press, N. Y., 1930. 332 pp., diagrams, tables. $6.00. Reviewed in *Mining and Met.*, **11** [284], 20 (1930).—This book presents a discussion of the theory of surfaces from the point of view of the molecular theory. By introducing the ideas concerning the shapes and mechanical and chemical properties of molecules which the theory of organic chemistry requires into the study of surfaces, new light is thrown upon phenomena hitherto classed as physical. A. discusses such matters as capillarity, adsorption, lubrication, surface tension, and catalysis from this viewpoint. E.J.V.

Colorimetric determination of small amounts of lead. B. JONES. *Analyst*, **55**, 318–20 (1930).—$PbCrO_4$ is precipitated in acetic acid solution, and the precipitate is washed with 2% KNO_3. It is then dissolved in HNO_3 and estimated colorimetrically against standard $K_2Cr_2O_7$ by the color developed in each on addition of diphenylcarbazide. H.H.S.

Technical Tables and Formulas. (Technischen Tabellen und Formeln.) W. MÜLLER. Walter de Gruyter & Co., Berlin and Leipzig, 1930. 151 pp. 1.80 Rm. Reviewed in *Mining and Met.*, **11** [284], 22 (1930).—A convenient collection of formulas and tables for electrical and mechanical engineers is presented. This includes data

most frequently wanted relating to heat, the strength of materials, machine elements, and electricity. The volume is of convenient size for the pocket. E.J.V.

Condensed Chemical Dictionary. ANON. 2nd ed. Chemical Catalog Co., New York. 550 pp. Price $10.00. Reviewed in *Brick Clay Rec.*, **77** [2], 116 (1930); *Rock Prod.*, **33** [15], 71 (1930).—The material in this edition is much more available than in the first edition since the book is more encyclopedic. The volume contains in brief form a large amount of valuable and authentic information in the chemical and ceramic fields. E.J.V.

Applied Inorganic Analyses. W. F. HILLEBRAND AND G. E. F. LUNDELL. Chapman and Hall, Ltd., London. Reviewed in *Refrac. Jour.*, **5** [58], 365 (1930); for abstract see *Ceram. Abs.*, **9** [1], 68 (1930). E.P.R.

Introduction to the Study of Wave Mechanics. (Introduction à l'étude de la mécanique ondulatoire.) LOUIS DE BROGLIE. 292 pp. Published by Hermann, Paris. Reviewed in *Chaleur ind.*, **11**, 308 (1930). A.J.M.

Modern Physics. (Physique Moderne.) G. CASTELFRANCHI. Translated by Quemper de Lavascol. 2 vol. 900 pp. Published by Albert Blanchard, Paris. Reviewed in *Chaleur ind.*, **11**, 308 (1930). A.J.M.

Roasting of chromite ores to produce chromates. H. A. DOERNER. Bur. Mines, *Rept. of Invest.*, No. 2999.—The Bur. of Mines is making a study of methods for beneficiating low-grade chrome ores found in the U.S. The purpose of the investigation is to study methods by which low-grade chromite can be converted to chromates, chromic acid, and chromic oxide, which should prove of value in the utilization of domestic ores. This paper is the first of a series dealing with an investigation of chemical methods of treating chromite and the possible application of these methods to the utilization of low-grade domestic ores. The series will include a study of methods of (1) roasting chromite to obtain chromates; (2) leaching the calcine; (3) purification of chromate liquors; and (4) conversion of chromates to other compounds, particularly chromic oxide and acid. The present paper deals with the reactions involved in roasting and leaching operations with reference to the effect of various common impurities, reagents employed, and conditions during roasting and leaching. R.A.H.

Flotation reagents, 1928. T. H. MILLER AND R. L. KIDD. Bur. Mines, *Rept. of Invest.*, No. 3004, 19 pp. (1930).—The development of flotation has been very rapid, and better understanding of the functions of flotation reagents has resulted in many changes in kinds and quantities of reagents used. It is the purpose of this report to present the information in such a manner as to be of value to the milling industry as well as to the manufacture of reagents. R.A.H.

PATENTS

Manufacture of chloride of potassium and carbonates of sodium and potassium. ROBERT D. PIKE, ROSS CUMMINGS, AND LEO V. STECK. U. S. 1,770,995, July 22, 1930. Process for producing a carbonate brine containing a predominating amount of potassium carbonate from wyomingite and a brine composed principally of a solution of sodium carbonate in water, which consists in grinding wyomingite and leaching under steam pressure with the brine, removing the leach solution from the solids, evaporating so as to crystallize out sodium carbonate monohydrate and removing crystals of the latter salt until the mol. ratio K_2O/Na_2O in the mother liquor is greater than 2.

Borax. AMERICAN POTASH & CHEMICAL CORP. Brit. 330,146, July 23, 1930. Calcined borax of a relatively dense nature, *e.g.*, containing 8 to 21% water, and having an apparent specific gravity of 0.5 to 0.9 is obtained from hydrated borax by subjecting the latter to the action of heated gases, *e.g.*, air, at a temperature below that at which the borax melts or dissolves in its water of crystallization.

General

Stress and strength. ANON. *Engineering*, **129** [3354], 543 (1930). A.A.

Feldspar standard adopted by industry. ANON. *Commercial Stand. Monthly*, **7** [1], 17 (1930); see *Ceram. Abs.*, **9** [8], 687 (1930). E.J.V.

Simulating sunlight. M. LUCKIESH. *Trans. Illum. Eng. Soc.*, **25**, 397–405 (1930).—L. discusses the health-giving properties of ultra-violet light from the sun, and gives a review of artificial sunlight sources emphasizing particularly a W filament-Hg-vapor arc lamp. M.A.B.

Windowless factories. ANON. *Ceram. Ind.*, **15** [2], 171 (1930).—E. E. Free says factories should be built without windows, claiming a saving of 5% in building costs and 40% in maintenance expenses. He states these buildings could be heated more equitably and ventilated more scientifically, and that artificial lighting could be an improvement over daylight, giving reasons. W.W.M.

Lubrication. ANON. *Abrasive Ind.*, **11** [8], 45 (1930).—This is a discussion of factors and design to be considered in deciding the grade of lubricant for a given purpose. Illustrated. E.P.R.

Cement-plant hazards at Detroit accident-prevention meeting. ANON. *Pit and Quarry*, **20** [9], 47–50 (1930).—The regional safety meeting of the Portland Cement Assn. held July, 1930, at Detroit provided valuable suggestions on safety matters. E.P.R.

Westinghouse salute to the ceramic industries over KDKA. ROSS C. PURDY. *Clay-Worker*, **94** [1], 35 (1930); for abstract see *Ceram. Abs.*, **9** [9], 801 (1930). E.J.V.

Anti-firedamp explosives. A. SEGAY. *Annales des Mines de Belgique; Queensland Govt. Mining Jour.*, **31** [6], 253 (1930).—S. describes the results of experiments and investigations carried out on explosives of the ammonium nitrate class for use in fiery mines. E.P.R.

Ventilation and control of siliceous dust on Witwatersrand gold mines. H. MITCHELL AND E. C. POLKINGHORNE. *Engineering*, **128**, 603–604 (1929).—The dust is produced underground by drilling, blasting, and the movement of the broken rocks. The injury rendered by the dust and some methods of control are discussed. A.A.

Mineral dust in factories. ANON. *Engineering*, **129** [3355], 571–72 (1930). A.A.

Atmospheric pollution. ANON. *Engineering*, **129** [3363], 825 (1930). A.A.

Recent developments in stoker design. H. D. SAVAGE. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 119–28 (1930).—Recent developments in stokers are discussed. Stokers for the larger size of steam-power boilers have undergone a different development from the smaller stokers. There has been a distinct advance in size, in practical combustion rates, and in the convenient arrangement of stokers in general. The problems of preheated air and the development of small stokers for domestic and industrial uses are also presented. E.P.R.

Distillation of coal. ANON. *Queensland Govt. Mining Jour.*, **31** [6], 231 (1930).—The New South Wales Government and representatives of a group of English capitalists are negotiating for the creation of a new industry at Newcastle, to cost nearly £3,000,000, for the distillation of coal and the manufacture of chemicals. E.P.R.

Effect of fouling on boiler efficiency. J. W. PIERSON. *Trans. Amer. Soc. Mech. Eng.*, **52** [12], 107–109 (1930).—The fouling conditions incident to the use of low-grade fuels with chain-grate firing with high relative ratings are dealt with. The data presented show the efficiency characteristics of an operating cycle with low-grade fuel compared to that which would exist when using a better fuel. E.P.R.

Problems of boiler feed-water. G. PARIS. *Chaleur ind.* [Special No.], pp. 107–13 (April, 1930). A.J.M.

Study of combustion in boiler furnaces. Practical temperature of combustion. H. GUILLON. *Chaleur ind.*, **11**, 298–303 (1930). A.J.M.

Thermal conductivity of boiler scale. ANON. *Arch. Warmewirt.*, Oct., 1929. A.J.M.

The three R's and enameling. PAUL E. COX. *Amer. Enameler*, **3** [5], 5–6 (1930).—A description and history of the Department of Ceramic Engineering at Iowa State College, located at Ames, Iowa, is given. J.N.U., Jr.

School of Ceramics of Caltagirone. ANON. *Le Ind. Silicati; Corriere ceram.*, **11** [6], 249–51 (1930).—The R. Scuola Industriale di Tirocinio (Sicily) was established for the purpose of reviving the art of the famous Sicilian and Caltagiron ceramics. Four courses in the theory and practice of production are given and the school is equipped with the most modern facilities. M.V.K.

New experimental and chemical research laboratories. ANON. *Pit and Quarry*, **19** [1], 113 (1929).—The Hercules Powder Co. is erecting near Wilmington, new experimental and chemical research laboratories. E.P.R.

Britain's latest industry. ANON. *Morning Post*, May 14, 1930.—The research laboratory of the Stourport works of Steatite and Porcelain Products, Ltd., was officially opened. The new industry employs 1300 workers, and the factory occupies an island site of 70 acres. Large insulators hitherto imported will be manufactured. Imperial Chemical Industries (I.C.I.) is backing the company. H.H.S.

Engineering markets of the world. I. A. J. LIVERSEDGE. *Engineering*, **129** [3361], 777–78 (1930); **II.** *Ibid.*, **130** [3366], 84 (1930). A.A.

Sale of clay in 1929 gains in quantity and value. ANON. *Brick Clay Rec.*, **77** [2], 86 (1930); *Blast Fur. Steel Plant*, **18** [8], 1355 (1930).—The quantity of clay sold by producers in the U.S. in 1929 amounted to 4,347,020 short T. valued at $14,850,744, showing an increase of 8% in quantity and 5% in value over 1928. The sales of kaolin amounted to 518,169 T. valued at $4,281,301, an increase of 4% in quantity and 5% in value compared with 1928. The clay of largest quantity and value is fire clay. The sales in 1929 were 3,178,865 T., valued at $8,107,796, increases of 14% and 8%, respectively, over 1928. Imports of clay amounted to 369,596 short T., valued at $3,543,154, a decrease of 0.2% in quantity but an increase of 1% over 1928. Exports of clay in 1929, of which fire clay amounted to 50%, amounted to 153,350 T., valued at $1,706,082, an increase of 27% in quantity and 23% in value over 1928. E.J.V.

Clay products exports show steady expansion. ANON. *Clay-Worker*, **94** [1], 36 (1930).—Foreign shipments of American brick and other clay building products continue to show an increase in all lines. Official figures for the first four months of 1930 are (1) fireclay brick, $286,907; (2) other refractory brick, $578,288; (3) refractory shapes, $700,059; (4) common brick and hollow tile, $88,407. E.J.V.

Work of the technical service during 1928. V. BODIN. *La Céramique*, **32** [491], 27–29 (1929).—The work of the technical service of the Ceramic Manufacturers Assn. of France includes studies of periodic and continuous kilns, tests of driers, researches on firing problems, and training courses. A.E.R.W.

Our Journal advertisements. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **9** [8], 233–34 (1930).—An appeal is made for advertisements for the *Journal of the American Ceramic Society*, after it has been pointed out that the advertising message there is being read. It is not merely for the financial profit that this plea is made, but to promote technical advances through the ability to increase the number of pages of printed matter as a result of the increased revenue. E.J.V.

Depreciation does not pay. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **9** [8], 232–33

(1930).—It is pointed out how an appreciation rather than a depreciation, and an understanding of fellow ceramic persons, firms, and products will result in larger profits and greater well-being. E.J.V.

Membership support. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **9** [8], 229–32 (1930). A membership analysis for 1928 and 1929 and for the first six months of 1930 is given, showing a steady growth in members, but a lack of support by the ceramic manufacturers. A plea is made to get more corporation members. E.J.V.

160 years of potting. ANON. *Pottery Gaz.*, **55** [638], 1283 (1930).—A brief description of the gathering of the employees of W. T. Copeland & Sons, to celebrate the 160th anniversary of the founding of the Spode-Copeland works by Josiah Spode is given. Illustrated. E.J.V.

Ceramic exhibition sponsored by Ironton Chamber of Commerce. ANON. *Clay-Worker*, **94** [1], 34–35 (1930); see also *Ceram. Abs.*, **9** [9], 802 (1930), under title "Promote Lawrence County clays at special meeting." Illustrated. E.J.V.

Josiah Wedgwood Bicentenary and the Ceramic Society. ANON. *Chem. and Ind.*, **49** [28], 496–98 (1930); *Gas Jour.*, **190** [3500], 827 (1930); *Engineering*, **130** [3364], 10 (1930); *Giorn. chim. ind. applicata*, **12** [5], 280 (1930); *Parnassus*, pp. 18–22 (May, 1930); *Design in Ind.*, p. 4 (1930); *Illus. London News*, **176**, 894–95 (1930).—The last article contains 23 photographs of early and modern examples of Wedgwood pottery. **Ibid.** ANON. *Pottery Gaz.*, **55** [638], 1263–67 (1930).—Discussions of and answers to the following questions are presented: "What is the reason for the occurrence of small patches of tarnish in gold-printed rim borders when using gold dust?" and "What is the cause of and cure for whirler plates?" For previous notices see *Ceram. Abs.*, **9** [9], 799 (1930).

Jubilee exhibition of Bohemian glass. ANON. *Chem. News*, **141** [366], 390 (1930).—An account is given of the exhibition now being held at Zelezny Brod, one of the chief centers of Czechoslovakian glass industry. Tables are given showing the increased production and value of blown and plate glass in the past seven years. G.R.S.

Society of Glass Technology. ANON. *Engineering*, **129** [3353], 525 (1930); see also *Ceram. Abs.*, **9** [8], 684 (1930). A.A.

American Society for Testing Materials. ANON. *Engineering*, **130** [3367], 105 (1930).—Some of the reports presented at the 33rd annual meeting of the Society held at Atlantic City, June 23 to 27, are taken up. A.A.

Standards Association of Australia. ANON. *Engineering*, **128**, 478 (1929).—A new organization was formed by the amalgamation of the Australian Commonwealth Engineering Standards Association and the Association for Simplified Practice. The other associations represented on the main committee are the Federal and States Ministries, the Institution of Engineers, Australia, the Australasian Institute of Mining and Metallurgy, the Australian Chemical Institute, the Bureau of Steel Manufacturers, the Associated Chamber of Manufacturers, and the Associated Chambers of Commerce. A.A.

New International Association for Testing Materials. ANON. *Engineering*, **129** [3351], 439 (1930).—The questions to be discussed at the next International Congress, which is to be held in Zürich in September, 1931, are taken up. A.A.

German glass technologists visit England. II. ANON. *Pottery Gaz.*, **55** [638], 1269–79 (1930).—A continuation of the account of the trip through English glass centers made by the German Society of Glass Technology. Illustrated. See also *Ceram. Abs.*, **9** [9], 800 (1930). E.J.V.

Second British Glass Convention. ANON. *Bull. Amer. Ceram. Soc.*, **9** [7], 228 (1930); *Pottery Gaz.*, **55** [638], 1280–82 (1930).—The complete program for the Second

Convention of the British Glass Industry held at Buxton from Sept. 17 to 20, 1930, is given. Illustrated. E.J.V.

Meeting of refractory manufacturers. ANON. *Tonind.-Ztg.*, **54** [54], 891–92 (1930).—The Union of German manufacturers of refractory products met June, 1930, in Jena. The following reports were discussed: (1) Kratzer, "Stability against Slagging of Refractory Materials;" (2) Illgen, "Influence of Grog Grain Size, Quantity, and the Firing Temperature on Physical Properties of Refractory Materials, especially on Tensile Strength at High Temperatures;" and two reports of Golla and Salmang, "Thermal Conductivity of Refractory Materials." M.V.K.

Philippine Research Institute. W. H. BROWN. *Mid-Pacific Mag.*, **39**, 439–44 (1930).—An account is given by the director of the Bureau of Science of the purposes and activities of the P.R.I. Of ceramic interest are the sections in archeology and geology. A photograph of a terraced mountain is shown. H.H.S.

Institute of British Foundrymen. ANON. *Refrac. Jour.*, **5** [58], 366–67 (1930).—The 27th Annual Meeting of the Institute of British Foundrymen was held at the Constantine Technical College, Middlesbrough, June, 1930. E.P.R.

Cast iron research. ANON. *Engineering*, **128**, 587 (1929).—The research work carried out by the British Cast Iron Research Assn. falls into three main sections: (1) Study of the behavior and possibilities of cast iron of all types under various service conditions and the influence of composition, annealing time, and other factors upon the properties of malleable cast iron. (2) Research work in cupola design and operation with the object of determining the best design of cupola for specified types and sizes of castings. (3) Investigation of most satisfactory types of molding sand, coke, and refractories for use in the foundries. Considerable progress that has been made in all branches of the experimental work conducted by the Association has been shown in the *8th Annual Report* covering the year ending June, 1929. A.A.

World Engineering Congress in Japan. ANON. *Engineering*, **128**, 651–53 (1929).—Papers given at the World Engineering Congress, held in Japan, October 25, 1929, are taken up. A.A.

World Power Conference. ANON. *Engineering*, **129** [3362], 804; **130** [3364], 26; [3367], 125–26 (1930); see also *Ceram. Abs.*, **9** [9], 801 (1930). A.A.

German chemical apparatus. ANON. *Tonind.-Ztg.*, **54** [53], 878–79 (1930).—At the annual meeting of the German Chemical Society, in Frankfurt a. M., the German Society of Chemical Apparatus held an exhibition of different chemical apparatus. Different objects made of glass, porcelain, metals, etc., were exhibited by 320 firms. A description of the objects exhibited with the names of firms manufacturing them, is given. M.V.K.

International Mining, Metallurgical, and Applied Geology Congress. ANON. *Engineering*, **128**, 688 (1929).—The 6th International Congress of Mining, Metallurgy, and Applied Geology held at Liége from June 22 to 28, 1930, is discussed. A.A.

English china industry. ANON. *Times Eng. Supp.*, **26**, No. 617 (May 3, 1930).—Since the safeguarding duty became operative, the home china market has largely been regained, and the German market has even been invaded with high-class ware. H.H.S.

Current conditions in the Belgian glass industry. WILLIAM G. BURDETT. *Commerce Repts.*, **15**, 115–16; **23**, 633 (1930); see also *Ceram. Abs.*, **9** [4], 270 (1930). E.J.V.

Glass manufacturing in China. ANON. *Mid-Pacific Mag.*, **39**, *Bull.*, No. 123, 13 (1930).—At the beginning of this century several modern glass factories came into existence in China, including the Glass Mfg. Co. at Poshan, the Yao Hsu Co. at Suchien, and the Yao Co. at Wuchang. Plate glass is mostly imported from Belgium and Japan,

but the Chi Ming factory in Shantung makes windowpanes. The Kai-Lun Mining Co. has organized the Yao Hwa glass factory near Chinwantao, utilizing river sand at Tank Ho and coal from neighboring mines. The Japanese are planning a factory in Manchuria, the coal to be supplied by the Fushun mines. H.H.S.

Glass manufacture in Poland. GILBERT REDFERN. *Commerce Repts.*, **30**, 229–30 (1930).—Poland's glass production in 1929 amounted to 109,000 T. as compared with 95,000 T. in 1928. The 1929 production comprised 59,800 T. of glass for bottles, 24,600 T. of fancy glassware, and 24,600 T. of window glass. The 1929 production represented the output of 68 glass plants employing a total of 16,500 workers, and accounted for the consumption of approximately 300,000 T. of coal, 150,000 T. of sand, 6100 T. of refractory materials, 27,000 T. of soda, and 7000 T. of Glauber's salt. Exports of glass from Poland during 1929 amounted to 1668 T. while the imports amounted to 10,767 T. E.J.V.

Industrial ceramics. ANON. *Corriere ceram.*, **12** [5], 185–95; [6], 237–45 (1930).—A description of the different branches of industrial ceramics in Italy is given with the number and regional distribution of the factories, and the values of imports and exports for the years 1913, 1926, 1927, and 1928. The divisions are (1) majolica and artistic porcelain, (2) earthenware and porcelain for domestic use, (3) terra cotta, (4) refractory products, (5) sandy clay for brick, (6) porcelain for technical use, and (7) artificial abrasive grinders. M.V.K.

Ceramic industry in Greece. ANON. *Tonind.-Ztg.*, **54** [46], 763–64 (1930).—A description of the ceramic industry in Greece is given. Three large plants are in operation, one near Athens and the two others on the Islands of Chios and Zante. They have zigzag kilns and use a gray mountain clay containing up to 30% fine lime. Other plants have small round kilns with a capacity of 30,000 brick. They are fired with olive wood and the products obtained are of a good quality. The pottery made is dried first in the shade and then in the sun. M.V.K.

Siberian silicate industry (Russian). I. F. PONOMAREV. Reprint from *Vestnik Sibirskikh Inzhinerov*, Nos. 7–12, 56 pp. (1927).—An analysis of the industry, methods used, products turned out, and equipment involved. (*C.A.*)

BOOKS AND BULLETINS

Sources of Calorific Energy and Industrial Heating. (Les sources de l'energie calorifique et le chauffage industriel.) EMILIO DAMOUR. Vol. I. 477 pp., 129 figs., plates. Price 110 F. Published by Ch. Beranger, Paris. Reviewed in *Rev. mat. constr. trav. pub.*, No. 249, p. 246 (1930). A.J.M.

Evaporating, Condensing, and Cooling Apparatus. E. HAUSBRAND. Translated by A. V. Wright. Ernest Benn, Ltd., London. 4th ed. Price 25s.

Budget Methods of the Brick and Clay Industry. METROPOLITAN LIFE INSURANCE CO. Reviewed in *Clay-Worker*, **94** [1], 32 (1930); *Brick Clay Rec.*, **77** [2], 105–10 (1930).—A report dealing with the extent to which budgeting methods have been successfully applied in the ceramic field. Among the topics discussed are budget periods and units, sales estimates, budgeting production, selling and administrative expenses, financial budgets, and installation and enforcement. Twenty brick and clay products manufacturers, trade associations, and trade journals coöperated in the preparation of the report. E.J.V.

Heat Management in a Boiler House. (Wärmewirtschaft im Kesselhous.) ERNST PRAETORIUS. Theod. Steinkopff, Dresden and Leipzig, 1930. 428 pp. 30 Rm. Reviewed in *Tonind-Ztg.*, **54** [32], 554 (1930).—The first part of the book deals with the theory and principles underlying technical heat management; the second part discusses the practical application of heat economy and the process of generating steam. See also *Ceram. Abs.*, **9** [7], 593 (1930). M.V.K.

Permanent Solidity of Building Materials. (Die Dauerfestigkeit der Werkstoffe und der Konstruktionselemente.) OTTO GRAF. 166 illustrations. Reviewed in *Tonind-Ztg.*, **54** [56], 935 (1930); for abstract see *Ceram. Abs.*, **9** [7], 594 (1930). M.V.K.

Practical Results in Removing Flying Ashes and Measuring Dust. (Practishe Ergebnisse auf dem Gebiete des Flugasche-Beseitigung und Staubmessung.) COMMITTEE ON DUST TECHNIQUE. Ver. deut Ing., ed., Berlin, 1930. 40 pp., 48 illustrations. 4.00 Rm. Reviewed in *Tonind-Ztg.*, **54** [55], 919 (1930).—This book, published by the Committee on Dust Technique discusses the recovery of waste dust and the influence of dust on the health of workmen in industries. New dust measuring apparatus are described. M.V.K.

Electrical Devices. ANON. *Abrasive Ind.*, **11** [8], 45 (1930).—Electrical Assn. of New York, Inc., has compiled a handbook of electrical information, in twelve sections, compiled by representatives of the twelve branches of the electrical industry. It is written in nontechnical language adapted to the understanding of all. E.P.R.

Patents, Trade-Marks, and Copyrights—Law and Practice. OSCAR A. GEIER. 128 pp. Published by Richards & Geier. Reviewed in *Abrasive Ind.*, **11** [8], 22 (1930). —The book covers the elements of patent, trade-mark, and copyright law and is written in understandable terms. E.P.R.

Book Reviews

Brands of Refractories. AMERICAN REFRACTORIES INSTITUTE. 8th ed. 70 pp. Issued June 10, 1930. This publication has for its aim the presentation, in compact, convenient form, of the brand names of the products of the American and Canadian manufacturers of refractories. In addition, the companies are listed alphabetically and in this section of the booklet the locations of their plants and the names of their products are given. Finally, the companies are classified geographically. The cordial reception accorded to the previous editions has led to the belief that this directory is valuable for reference by the many users of refractories, especially purchasing agents, metallurgists, and engineers in the industries who depend upon high temperatures in their plant production and operation. Copies of this booklet may be obtained from the American Refractories Institute, Oliver Building, Pittsburgh, Pa. See also *Bull. Amer. Ceram. Soc.*, **9** [9], 278 (1930).

Pukall's Ceramic Contribution. (Pukall's Keramische Abhandlungen.) W. PUKALL. Published by Sprechsaal, Müller and Schmidt, Coburg, Germany, 1930. 350 pp. In this volume the many papers published by W. Pukall during his directorship of the State Ceramic School at Bunzlau, have been collected. It was a wise decision on the part of Sprechsaal to undertake this labor of love and to offer to the clay-working world the results of such a rich experience. The variety of topics covered in this work may be realized when we mention the following subjects: the lead question; crystalline glazes; fine stoneware; new hard-fire colors for porcelain; composition of old Egyptian ceramics; ceramic bodies; whiteware glazes free from boric acid; the phenomena of firing; the drying of ceramic bodies; clay filters and their properties; inorganic syntheses; water glass. Since these discussions are the result of years of painstaking work and an intimate aquaintance with ceramic problems, it would seem that the book deserves a place in any ceramic library. Not the least important quality of the book is its value as a source of suggestions which arise naturally in the course of its reading. A.V.BLEININGER

TEXTURE•

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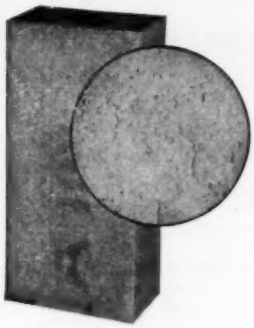

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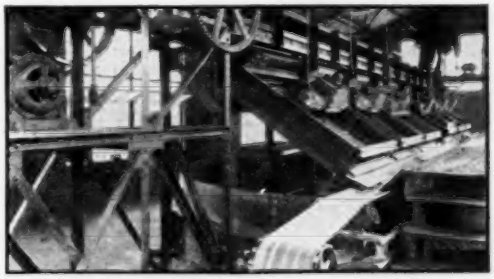

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Ceramic Educational Directory

THE OHIO STATE UNIVERSITY
Department of Ceramic Engineering, COLUMBUS, OHIO

Curriculum—Ceramic engineering and technology. Advanced research in coöperation with State owned plants and Federal Government

SIX INSTRUCTORS *Head of Department:* ARTHUR S. WATTS
Founded 1895 *Research Professor:* GEORGE A. BOLE

NEW YORK STATE SCHOOL OF CLAYWORKING AND CERAMICS
ALFRED UNIVERSITY, ALFRED, NEW YORK

Curriculum—Ceramic Engineering, Ceramic Chemistry, Appied Art

NINE INSTRUCTORS *Founded 1900* *Director:* CHARLES F. BINNS

RUTGERS UNIVERSITY
NEW BRUNSWICK, N. J.

Ceramic Department founded 1902
Curriculum—Ceramic Technology and Engineering

THREE INSTRUCTORS *Director:* GEORGE H. BROWN

UNIVERSITY OF ILLINOIS
Department of Ceramic Engineering *Founded 1905* URBANA, ILLINOIS

Curriculum—Ceramic Engineering and Ceramics, the latter is a non-engineering course in the technology of ceramic products

SIX INSTRUCTORS and a research associate *Head of Department:* C. W. PARMELEE

IOWA STATE COLLEGE
Department of Ceramic Engineering, AMES, IOWA

Curriculum—Ceramic Engineering major, Ceramic Technology and ornamental ceramics

FOUR INSTRUCTORS, TWO COURSES *Founded 1906* *Head of Department:* PAUL E. COX

THE UNIVERSITY OF NORTH DAKOTA
Department of Ceramics and Ceramic Engineering, GRAND FORKS, N. D.

Curriculum—Ceramic Art and Technology

FIVE INSTRUCTORS *Founded 1910* *Director:* A. W. GAUGER

UNIVERSITY OF WASHINGTON
Department of Ceramic Engineering, SEATTLE, WASHINGTON

Curriculum—General ceramic engineering with research in ceramics and non-metallics
Coöperation with the U S. Bureau of Mines

Director: HEWITT WILSON *Founded 1918* *Assistant:* J. H. YATES

UNIVERSITY OF SASKATCHEWAN
SASKATOON, SASK.

Curriculum—Ceramic Engineering

TWO INSTRUCTORS *Founded 1921* *Head of Department:* W. G. WORCESTER

PENNSYLVANIA STATE COLLEGE
Department of Ceramics, School of Mines and Metallurgy
STATE COLLEGE, PENNA.

Curriculum—Ceramic Engineering

Head of Department: J. B. SHAW *Founded 1923*

GEORGIA SCHOOL OF TECHNOLOGY
ATLANTA, GEORGIA

CERAMIC DEPARTMENT *Curriculum*—Ceramic Technology and Engineering
TWO INSTRUCTORS *Founded 1923* *Director:* A. V. HENRY

VIRGINIA POLYTECHNIC INSTITUTE
BLACKSBURG, VIRGINIA

Curriculum—Ceramic Engineering

Founded 1929 *Head of Department:* J. W. WHITTEMORE

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING
RALEIGH, NORTH CAROLINA

Department of Ceramic Engineering founded 1923 *Curriculum*—Ceramic Engineering
THREE INSTRUCTORS *Head of Department:* A. F. GREAVES-WALKER

WEST VIRGINIA UNIVERSITY
MORGANTOWN, W. VA.

Ceramic option course founded 1924

Curriculum—Chemical and engineering principles applies to ceramic manufacture

TWO INSTRUCTORS AND TWO ASSISTANTS *Director:* W. A. KOEHLER

UNIVERSITY OF TORONTO
TORONTO, CANADA

Founded: University, 1827; Department of Metallurgy, Ceramic Division, 1925

Curriculum—Ceramic Engineering and Technology

TWO INSTRUCTORS *Principle Instructor:* ROBERT J. MONTGOMERY

MISSOURI SCHOOL OF MINES AND METALLURGY
OF THE UNIVERSITY OF MISSOURI, ROLLA, MO.

Cirriculum—Ceramic Technology and Ceramic Engineering

TWO INSTRUCTORS

Director: CHAS. H. FULTON *Founded 1926* *Head of Department:* M. E. HOLMES

UNIVERSITY OF CINCINNATI
CINCINNATI, OHIO

Dept. School of Applied Art, Ceramic Dept.

Curriculum—Coöperative training in ceramic art and technology to develop designers for ceramic industries

Founded 1926 *Head of Department:* HAROLD S. NASH

THE OHIO STATE UNIVERSITY
Department of Fine Arts, COLUMBUS, OHIO

Curriculum—Ceramic art and technology to train artists for the ceramic industries

THIRTEEN INSTRUCTORS *Head of Department:* JAMES R. HOPKINS

Founded 1927 *Professor of Ceramic Art:* ARTHUR E. BAGGS

UNIVERSITY OF OKLAHOMA
NORMAN, OKLAHOMA

Dept. of Ceramics, School of Fine Arts *Curriculum*—Ceramic Art

Founded 1927 *Head of Department:* JOHN N. FRANK

UNIVERSITY OF ALABAMA
UNIVERSITY, ALABAMA

Ceramic Option Course, Founded 1928

Curriculum—Technical ceramic courses given by Dept. of Chemistry and Metallurgy

TWO INSTRUCTORS *Director:* STEWART J. LLOYD *Ceramics:* T. N. MCVAY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS.

Curriculum—Graduate Study and Research in Ceramics

FIVE INSTRUCTORS *Founded 1929* *Head of Course:* F. H NORTON

LOUISIANA STATE UNIVERSITY AND AGRICULTURAL AND MECHANICAL COLLEGE
BATON ROUGE, LA.

Curriculum—Optional Courses now given by the Department of Geology

THREE INSTRUCTORS *Ceramics Dept. founded 1925* *Head of Dept.:* H. V. HOWE

STANFORD UNIVERSITY
Department of Mining Engineering, STANFORD UNIVERSITY, CALIFORNIA

Curriculum—Two-year graduate course in ceramic engineering, offering various combinations with mining and metallurgical engineering. Research in ceramics and non-metallics.

Director: THEODORE J. HOOVER *Founded 1925* *Professor in charge:* W. F. DIETRICH

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE
STILLWATER, OKLA.

Department of Ceramics, School of Engineering

Curriculum—Ceramic Option—Chem. Eng.

ONE INSTRUCTOR *Founded 1928* *Head of Dept.:* L. F. SHERRAR

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CLEVELAND

BULLETIN

of the

AMERICAN CERAMIC SOCIETY

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific, and Art Questions, and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 9 **October, 1930** **No. 10**

EDITORIALS

WHAT YOUR SOCIETY IS DOING FOR YOU

Your editor used to be skeptical about the "self-starter" feature of letters written in commendation of things published. They have seemed to be in response to inquiries from the editor. We have had reasons during the past year, however, to know that many of these commendation letters are self-prompted.

Letters complimentary of the *Journal* papers, the *Abstracts*, and the Editorials are increasing in number. They have been received from members and nonmembers, from executives and investigators, from abroad and from home. They have been greatly appreciated; they have been nice rewards for labor spent. We have been delighted to pass them on to the authors.

It would be idle to tell an appreciative thinking man about the large values there are in the papers published in the *Journal* and in the *Abstracts*. There are many, however, who do not stop to evaluate the contents of the *Journal* and *Abstracts*. There are those who have not learned to search them for information and ideas.

The inquiries received from remote parts of the world and from scientists, plant workers, ceramic artists, and engineers, establish the fact that the

monthly publication of your SOCIETY is appreciatively read by those who are seeking for ceramic information. Your *Journal* is recognized as a reliable "store house" of facts worth knowing and of inspirations worth having. To those who are not already appreciative of the value, it is not amiss to suggest that what is worth while to so many persons must be worth while to each person.

Letters are received telling that the abstracts are worth much more than the annual subscription. Where else can they be obtained? How much would it cost to make them privately?

Several persons have told of the large value they put on the annual index which is published in December together with the names and publishers' addresses of the journals and books from which abstracts have been obtained.

To publish so much valuable information costs more money than is received from membership subscriptions and advertisements. More money must be collected by the SOCIETY. The members have already voted to increase the membership dues to $12.50 per year but this will not be sufficient to cover the growing costs of publishing the increasing number of papers and abstracts available.

The ceramic corporations should be supporting this work with corporation membership of $25.00 per year. It is the manufacturing firms that benefit most largely, hence they should make it possible for the individuals to increase this coöperative service without undue increase in financial burden to the individuals.

Then too, the *Journal* and *Abstracts* are not the only nor the end purposes of the AMERICAN CERAMIC SOCIETY. They are only two of the means used "to promote the ceramic arts, science, and technology." The SOCIETY committees compile bibliographies, standards, and data, and promote research. The SOCIETY holds meetings and is active in all means available for promoting ceramic research and education. Each clay, glass, and enamel ware manufacturing company are beneficiaries of these activities. It is of material importance to each ceramic manufacturing concern that financial means be provided for extending these activities. This they can do as Corporation Members paying $25.00 per year. Will you sell them this opportunity?

937 Seventh St.,
Santa Monica, Calif
Sept. 4, 1930.

My dear friend Purdy:

I often wonder why I, a concrete engineer, belong to the AMERICAN CERAMIC SOCIETY. I'll answer myself: "I get more than I pay for in the *Journal*."

I believe I can add to the value I receive. In your *Abstracts*, in the September number (Vol. 9, No. 9 of the *Abstracts*), page 706, you show three articles by C. R. Platzmann, on concrete, abstracted by M. V. Kondoidy, with other articles. It is

desirable for me to get the entire articles of such foreign articles sometimes and I am writing to inquire what M. V. K. would charge me to give me a complete translation of such articles, and if possible give me a price on future articles on concrete or other desirable matter I may need.

I believe if you would make a note in the *Journal* offering to furnish these complete articles translated, which are now only abstracted, you would do a good turn both to the translator and a large number of members like myself, who can use the matter shown.

My compliments on the fine abstracting you are doing; it is very valuable, and as I have already noted, more than worth the money.

With warmest personal regards, I am, yours very sincerely,

W. A. COLLINGS.

NATIONAL STRUCTURAL CLAYWARE MANUFACTURERS ASSOCIATION

The present mess resulting from having a separate trade association for each type of clay product is wasteful of money, time, effort, and of opportunity to combat effectively the competition of nonceramic materials. Why men who have business acumen cannot see that this situation is defeating their associated efforts and cramping their own personal business is one of the psychological wonders.

What is there to a face brick that distinguishes it from a common brick other than in the care to produce desired facial appearance? There is so little in their production and use that is not of common consideration that there is absolutely no reason for there being two trade associations of brick manufacturers.

Most brick manufacturers could switch production from face to common and paving brick and even to structural tile without much effort or delay. There are plants in which these changes in product are customarily made. The character of the clay and the breadth of sales interests are the only limiting factors.

The overlapping between face brick, structural tile, and terra cotta is rapidly increasing. It has reached that stage where the terra cotta manufacturer must produce machine-made ashlar, trims, and interior terra cotta or lose business to the brick and structural tile makers. This overlapping is involving the wall, floor, and roofing tile, and even the enameled iron tile makers.

In fact, in the production and in the contacts with architects, contractors, and builders, the ceramic building product makers have almost entirely the same problems. The differentiations in manufacturing and in product uses are rapidly disappearing.

"Divided we fall." Against the competitive onslaught of nonceramic material producers, the ceramic ware manufacturers are impotent. We do not have data in usable form showing the superiority of ceramic ware for

constructional purposes. In the data books used by architects and engineers, ceramic products have an extremely inferior rating.

Ceramic manufacturers are not negotiating for studies being made on their materials in the university laboratories to any such extent as are the manufacturers of nonceramic materials. Ceramic manufacturers are not availing themselves of these publicly financed research facilities and thus are depriving themselves of opportunities to get unbiased and acceptable data into the literature. Thus, also, the ceramic manufacturers are depriving themselves of this most effective way of impressing the graduating architects and engineers with the superior qualities of ceramic construction ware. They are giving their nonceramic competitors the right of way in these publicly financed institutions of research and education.

"Divided we fall" and falling we are, just because of unfounded prejudices and organization jealousies. As long as the separate trade associations are maintained, ceramic manufacturers will continue to lose in their contest with nonceramic materials.

In place of destructive competition between ceramic product producers there should be and could easily be an effective union of forces that would cost the ceramic manufacturers less money, less time, and less effort and produce for them more business.

POSSIBILITIES OF A RESEARCH LABORATORY DEVOTED TO CERAMIC INDUSTRIAL DESIGN[1]

By Frank Sohn[2]

In considering the possibilities of a research laboratory for ceramic industrial design, I was at first inclined to consider only the practical side of the subject. It seemed best, however, to bring out the chief reasons for establishing such an institution, and to leave the details to be worked out when the work becomes a reality.

A fascinating vista was opened before me, when this subject was brought to my attention. I thought of this great age that is just beginning and which is destined to surpass any previous age in history, and in which it is our privilege to be living. I thought of the revolutionary and astounding advances that have been made in engineering, bringing to us buildings and bridges and other structures surpassing any previous efforts for practical purposes and dramatic intensity. I thought of the developments in chemical research that have built up a world of new materials and substances

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[1] Presented at the Annual Meeting, American Ceramic Society, Chicago, Illinois, February, 1929.

[2] President, Art Director's Club; Art Director, Vitrolite Company, Chicago, Ill.

around us, changing the whole complexion of our surroundings, and of the discoveries and inventions in electricity, so numerous and so rapid in their succession that we have almost become immune to sensations of novelty and surprise.

We could go on to radio, locomotion, surgery, and even psychology, and note greater advances in a few years than in all previous history. The age is moving so fast that the human mechanism has a hard time adjusting itself to these changes. Our sensibilities, formed in response to the many centuries of contact with nature, faced a difficult problem of adjustment when civilization began. Each successive advance of civilization has taken us further from nature and necessitated setting up compensating stimuli to prevent the human mechanism from going to pieces. This effort of adjustment to changing environment has led man to modify the superficial aspect of his surroundings so as either to make a painful existence more endurable, or to realize a greater joy from an agreeable existence. This kind of effort we call art, and the conscious development and application of art forms for a given purpose we call design. I should give as a definition of art that it is man's effort to effect an adjustment of his senses to the changes in his environment, or in other words, to the advances of civilization.

At this time we have a considerable conservative body, resisting the changes brought in by the industrial age and referring regretfully to the good old times. We have the great middle class joyfully buying automobiles, electric signs, motion picture cameras, and radio sets, and frankly enjoying them; and in the advance guard we have those individuals of vision and imagination whose sensibility has not been lulled to sleep by the narcotics of the periods and the classics, and whose prophetic minds see in the developments of this great industrial age the basis of a new culture based on true appreciation of human possibilities. They conceive a religion based on the scientific adjustment of mutual relationships for the greatest good to all mankind. They forecast a new art expression that shall be scientifically adjusted to both the individual and collective esthetic needs of human sensibilities. They believe further that this new culture, religion, and art expression will result in a greater satisfaction and enjoyment of life by all classes than has ever before been possible.

When we ask ourselves what has made possible these great advances in engineering, chemistry, and electricity we cannot evade the laboratory. Without the experimental laboratory the other contributing factors could not even have gotten started.

In contrast to the advanced position of the sciences and mechanics in industry, the standing of art in industry is very low. There has been an awakening in this respect, but the accomplishments so far make rather a sorry showing. It is even questionable as to whether the period of 1830

to 1900 in Europe, and to 1925 in this country, will not go down in art history as the ugliest and most sterile of all art periods.

Two principal reasons suggest themselves as being responsible for this condition. First, dependence on the art forms of the past because of a combination of snobbishness, ignorance, and laziness on the part of the would-be cultured and artistic classes; and second, a lack of knowledge of the purpose of art by the industrial and scientific classes. Art, for about one hundred years past, has been almost entirely separated from life and the artist has, more often than not, devoted his talents to helping himself and a limited audience to escape from the supposed ugliness of contemporary life, especially the industrial part of it. And the scientist and business man, living the true romance of our time without knowing it, has, until recently, been content either to ignore these art efforts or to submerge his usually intelligent outlook and let this kind of artist or architect surround him with classical halls, turkish dens, and studies heavy with medieval mysticism. His industrial products, he has permitted the same type of artist to embellish with Greek frets and acanthus scrolls, or other equally meaningless incumbrances to conceal their practical purpose and disguise the honest materials they were made of.

There have, indeed, been eminent art critics during this period, but each critic has been riding his particular hobby and colliding noisily with the others. There have also been talented artists not content to re-create the past or to take refuge in the externals of nature, but who have marched arm in arm with their age. But we find these progressives as well as the conservative groups of artists split up into various schools of expression, with little harmony of purpose except the vigorous denunciation of each other. And the bewildered public and the industrial world views this spectacle of confusion and wonders what it is all about.

What then is necessary to bring design to the high level of the physical sciences? Principally two things: First, recognition of the fact that design is a science having to do with the setting-up of sense stimuli and their reception by the human organism. Second, establishing laboratories where esthetic needs and reactions can be studied and classified and the means determined for gratifying or correcting them. This laboratory would be a place where the artist, designer, critic, physician, psychiatrist, and various kinds of other scientific gentlemen would gather together all existing data, sift out the useful, observe the behavior of human beings in reaction to all kinds of visual stimuli, and determine the correct dosage of color, form, value, and movement to fit any particular purpose or accomplish any given reaction on any given group of people.

I shall try to be more specific. What must industry do to justify its existence? Here are at least a few of the things that industry should do:

(1) Make goods that have a useful purpose and are perfectly adjusted to that purpose.
(2) Make goods that are profitable to their producer.
(3) Establish contacts with the greatest number of people who can benefit by their use.
(4) Make goods that people will enjoy seeing and using.
(5) Make goods that are part of a unified ensemble.

Now is it likely that a research laboratory of design could help in accomplishing these ends? Let us consider the personnel of such an institution. Suppose that it were constituted something like this:

(1) A director and assistant director, (2) four (or more) creative designers, who are also expert students of design and would represent the different branches of the industry, (3) two writers and investigators, (4) a secretary and three stenographers, and (5) a file clerk and perhaps an office boy.

These would work in collaboration with (1) scientists, (2) physicians, (3) psychiatrists, (4) groups of art directors, (5) authorities in art education, and (6) experts in retail establishments.

Now just what would their activities consist of? I cannot name all of them but this list will at least keep them busy:

(1) Make an intensive study of the reactions of human sensibilities to form, color, movement, etc., and formulate principles concerning their application to human needs.
(2) Study possibilities of form, texture, and color, etc., not only in ceramic materials but also in all accessory materials.
(3) Establish esthetic principles applying to the expression of ceramic materials by themselves and in combination with other materials.
(4) Formulate existing decorative processes and pass on new ones.
(5) Study function of ornament and formulate basic laws for its creation and use.
(6) Work up progressive design schemes showing appropriate uses of ceramic materials in combination with other materials.
(7) Keep in touch with international design developments through magazines, books, catalogues, and visits to exposition, showrooms, factories, and schools.
(8) Assist firms to establish design departments.
(9) Survey of available designers.
(10) Survey of schools of design.
(11) Forecast style trends.
(12) Advise firms in regard to character of new designs and models.
(13) Conduct competitions for industries.
(14) Coöperate with advertising departments and agencies to help make advertisements fit the product.

You may say that this kind of an institution is impossible. As proof to the contrary, I only need to remind you of the activities and accomplishments of the research laboratories of such firms as the General Electric

Company and some of our leading technical institutes. If it can be done in electricity or chemistry, it can also be done in design.

But the benefits to the ceramic industry and to humanity at large would be so considerable as to make the effort well worth while. We could then practise design knowing ourselves to be very important factors through our ability to make people happy or hungry or somber or devout at will, because of our scientific knowledge of form and color and how to apply them. The manufacturer would be spared endless expense with the prospect of ruin just around the corner and instead would be faced with the certainty that people would like his products and buy them at a good price.

I feel a considerable personal responsibility in discussing this subject, for undoubtedly the hard-headed business men who guide the destinies of the ceramic industry are going to rush out immediately to raise the money to start this laboratory. Miracles have happened before, and I for one would like to be a party to an institution of this kind, even though I were only the office boy.

ACTIVITIES OF THE SOCIETY

LOCAL SECTION NEWS

1930 Report of the Pacific Northwest Section

The 1930 Annual Meeting of the Pacific Northwest Section of the AMERICAN CERAMIC SOCIETY was held in Seattle on January 17 and 18. The following program was given with President E. E. Saunders, presiding:

(1) "Purification of Clays by Washing," by Wurth Kriegel, Univ. of Washington.
(2) "Practical Clay Products Research," by A. L. Miller, Executive Officer, Dept. of Civil Engineering, Univ. of Washington.
(3) "Cyanite in Southern Idaho," by G. L. Rogers, Engineer, Gladding, McBean and Co.
(4) "Geology of Eastern Washington with Reference to the Formation of Kaolin," by G. E. Goodspeed, Univ. of Washington.
(5) "A Method of Eliminating Auger Lamination," by Neal Fosseen, Washington Brick Lime and Sewer Pipe Co.
(6) "Preliminary Note on the Study of Refractories in Recovery Furnaces for Sodium Liquors in Pulp and Paper Plants," by J. A. Cunliffe, Univ. of Washington.
(7) "Saving Coal in Kiln Firing," by Howard Mansur, Engineer, Gladding, McBean and Co.
(8) "Dewatering Clay Suspensions by Electricity," by C. E. Curtis, Univ. of Washington.
(9) The Wenatchee Fire Clays," by L. A. Martin, Gladding, McBean and Co.

A second session was held in coöperation with the Pacific Northwest Brick and Tile Association, with their president, H. R. Kreitzer, presiding.

(1) "Report of the Testing of Pacific Northwest Brick and Tile," by A. L. Miller, Univ. of Washington.
(2) "Design Requirements for Industrial Buildings, "by W. R. Engstrom, Engineer for the Austin Co.
(3) "Design Requirements for Business Sub-Center Buildings," by R. C. Erskine, Seattle Real Estate Board.

The following officers were elected for the year 1930:

President, Alex H. Corbett, Granger Clay Products Co., Yakima, Wash.
Vice-Pres., P. L. Lingren, Gladding, McBean, and Co., Portland.
Secretary, Hewitt Wilson, Univ. of Washington.
Treasurer, H. O. Thompson, Builders' Brick Co., Seattle.
Trustee for Brick and Tile Division, W. J. Howard, Secretary, Pacific Northwest Brick and Tile Assn.
Trustee for Terra Cotta and Pottery, A. B. Fosseen, Washington Brick Lime and Sewer Pipe Co., Spokane.
Trustee for Sewer Pipe, W. E. Lemley, Gladding, McBean, and Co., Taylor, Wash.

The committees appointed by the president are as follows:
Program, Chairman; P. L. Lingren, Portland; G. L. Rogers, Renton; Henry Hoffman, and Walter Howard, Seattle.
Membership, Chairman: H. O. Thompson; Phil Corbett, vice-chairman for Oregon, P. L. Lingren, Portland; Tom Hall, Moscow.
Nominating, Chairman: Harry Kreitzer, Ray R. Smith, and A. B. Fosseen.
Entertainment, Chairman: Clifford Houlahan, Albert Armstrong, J. Parfitt (Victoria).

The first year of research and testing work was admirably performed by A. L. Miller and his reports formed the basis for the two days' program. Nineteen firms, representing practically all the brick and tile industries of the Pacific Northwest, contributed $1000.00 for testing 66 batches of building brick, 27 batches of partition tile, and 20 batches of load-bearing wall tile. These were tested under the A.S.T.M. specifications and the results indicate that the northwest is producing an excellent grade of clay building products.

TREASURER'S REPORT

PACIFIC NORTHWEST CLAYWORKERS' ASSOCIATION

(As of December 31, 1929)

Receipts		
Balance on Hand, Jan. 1, 1929, Gen. Fund	$ 38.94	
Balance on Hand, Jan. 1, 1929, Bldg. Code Fund	36.02	$ 74.96
Receipts from Dues	$ 74.00	
Fellowship Fund Receipts	825.00	899.00
		$973.96
Total Receipts		
General Fund Disbursements		
Printing, Mimeographing, and Postage	$ 58.77	
Fellowship Fund Disbursements		
Alfred Miller	$700.00	
Auto Freight Bills	18.70	
Mimeographing	14.00	732.70
Total Disbursements		$791.47
Balance, General Fund	$ 54.17	
" Fellowship Fund	92.30	
" Building Code Fund	36.02	
Balance per Bank Statement—December 31, 1929		$182.49

Respectfully submitted,
H. O. Thompson,
Treasurer

Pacific Northwest Section and the Pacific Northwest Brick and Tile Association Summer Meeting at Victoria, B. C.

The Victorian group of ceramists have perfected the art of entertainment to a fine degree of perfection. They have, of course, some natural advantages of mountain scenery, magnificent hotels, a charming English type of city, excellent golf courses, many wonderful harbors, inlets and fiords of salt water, and other types of liquid refreshment.

Some eighteen clayworkers and technical allies gathered at the Empress Hotel, Friday afternoon August 1, after traveling by boats and ferries from Seattle and Vancouver, to listen to the following program. The new president, Alex Corbett, presided.

(1) "Research Problems of the Clay Industry," by A. L. Miller, Department of Civil Engineering, Univ. of Washington.
(2) "Technology in the Clay Industry," by Dean R. W. Brock, Head of the College of Applied Science, Univ. of British Columbia, Vancouver, B. C.
(3) "Discussion of Methods for Making Light Weight Partition Tile," by Hewitt Wilson, Ceramic Engineering Dept., Univ. of Washington.

Saturday afternoon's program consisted of a visit to the new plant of the Victoria Brick Company on the north boundary line of the city itself. Both soft-mud and stiff-mud clay products are made of a local red-firing clay. This company has just completed a new large drier and an attractive office which displays a complete line of its facing products. Business must have been excellent in Victoria from the size and quality of the cars in which they transported us to Butchart's Gardens, the Dominian Astrophysical

Observatory, and the wonderful 46-mile Malahat Drive. Mr. Butchart is a cement manufacturer, who, after extracting a wealth of limestone from his quarries reconverted a portion of the excavation into a sunken garden, filled with flowers and shrubs. The gardens are a triumph of landscape gardening, presenting an effect of massed coloring against the rocky and forested background that is most enchanting. He has opened these gardens to the public; the Government has built a new highway and visitors from all over the world visit them. They are particularly attractive to Californians in the summer time.

The afternoon tour included a ferry ride over Saanich Arm and a trip over the Malahat Drive along the water. The Canadians proved delightful hosts and efficient comrades.

A partial list of those in attendance included:

John L. Burns, Clayburn Company, Ltd., Vancouver, B. C.; A. L. Miller, Univ. of Washington, Seattle; H. Burnet, W. M. Horie, and E. G. Baynes, Port Haney Brick Company, Ltd., Vancouver, B. C.; J. D. Cameron, Gabriola Shale Products Co., Ltd., Victoria, B. C.; Alex Ree, Manager, Clay Products Coöperative Assn., Vancouver, B. C.; Neal Fosseen and Edward Burkhalter, Washington Brick Lime & Sewer Pipe Co., Spokane, Wash., R. W. Brock, Univ. of British Columbia, Vancouver, B. C.; J. C. Parfitt, Victoria Brick Company; W. J. Howard, Pacific Northwest Brick & Tile Association, Seattle; F. T. Houlahan, Builders' Brick Co., Seattle; W. A. Luney, Baker Brick and Tile Co., Victoria, B. C.; O. K. Edwards, Willamina Clay Products Co., Portland, Ore.; Alex Corbett, Granger Clay Products Co., Yakima, Wash.; Hewitt Wilson, Univ. of Washington, Seattle.

AMERICAN CERAMIC CONGRESS, CLEVELAND AUDITORIUM

February 23–27, inclusive, 1931

The Meetings and the Exposition to be held in Cleveland next February constitute the Second American Ceramic Congress. The Meetings, under the auspices of the seven industrial Divisions, will be held simultaneously in the different meeting rooms of the Auditorium. Bulletin boards announcing the papers being read before each of the Divisions will be posted in each of the several rooms so that those attending may be informed of the status of the program at any particular moment.

Each of these Divisions is planning to limit the program to four or five papers per session, making it possible for twenty papers per Division. It is going to be an honor to be on the 1931 program before any one of the Divisions. The Divisional officers are going to keep in mind the fact that the time of the attending delegates must be conserved and spent only on hearing the very best papers given in the shortest possible time, with ample opportunity for discussions.

The American Ceramic Exposition, with its 165 booths, has received a great deal of attention and support. One-third of the space has already been sold. With the returning confidence in the business conditions, there is an increasing interest shown in the inquiries concerning space. It is confidently expected that during October, practically all of the space will have been taken by manufacturers of ceramic products of all sorts, and by producers of ceramic equipment and materials.

The purposes of this second Ceramic Congress are the same as those of the first Congress, that is, an intensive education regarding the size and character of ceramic manufacturing in this country. There is a great need for ceramic manufacturers in each of the several lines to know the large variety of ceramic ware that is being manufactured, and the large number of uses to which it is being adapted.

Underlying the compounding, forming, and making serviceable ceramic ware of all sorts, there are the same fundamental principles of science, engineering, and artistry. There is an urgent need for ceramic manufacturers to become familiar with the interdependence of each and all of the several lines of ceramic manufacturing covering clay, glass, and vitreous enamels. There is much to be learned and much appreciation to be sought before the ceramic manufacturers will unite in support of ceramic education and research, especially in securing their just share of the federal and state appropriations which are spent in bureaus and schools. These educational features of the Meetings and Exposition, which constitute this Second Annual Ceramic Congress, are directed to the ceramic manufacturers. It is hoped that this Congress will do a great deal to develop a unity in purpose and activities in support of ceramic research and education.

The work of the ceramic artist, scientist, technologist, and engineer is without avail unless the product serves more efficiently the purposes for which it is purchased by the ultimate consumer. It is also to the interest of the ceramic artist, technologist, and engineer that there be the largest possible employment of his products. This means that the public must be cultivated.

For altogether too long a time have the ceramic manufacturers continued serenely and falsely on the supposition that because their product has been made and largely used with little competition for many centuries, they will continue to have a demand increasing with the increasing population. The ceramic manufacturers must awaken to the fact that their products are now in competition with nonceramic products having supposed equal serviceability. The ceramic manufacturers are under a false impression of security. Their business is not secure; in fact it is not holding its own in competition with the nonceramic products. It is imperative that the ceramic manufacturers awaken to this situation and cultivate prospective purchasers, making their ware known for its superior serviceability.

Ceramics, industrially and professionally, is not generally known. There is no appreciation on the part of the public of the extent of ceramic manufacturing in the United States. There is no appreciation by the general public of the high quality of the ceramic ware produced in the United States. In fact, it is the general impression that American ceramic ware is inferior in design and quality to foreign made ceramic ware, and to nonceramic competitive products. This situation must be changed if the ceramic industries are to enjoy their share of American business, and attain the needed prestige in legislative bodies that will secure the proportionate financial support of ceramic education and research which they actually deserve.

There must be established a broad and thorough program of investigations and tests of the adequacy and deficiency of ceramic ware for every possible purpose. This program must be carried on in the universities and in the public and semi-public research institutions. In no other wise can the ceramic industries hold their own in competition, and in no other wise can the purchasing public be informed. Ceramic congresses are of vital importance to the ceramic manufacturers as an educational opportunity to themselves and to the purchasing public.

It is important that the manufacturers and the ceramic artists, scientists, and technologists participate in the Meetings and in the Exposition this coming February in Cleveland. To plead difficult times and slow business will have to be accepted as admission that the ceramic business and the ceramic manufacturers are far more backward than most all of the other industries because the records of the meetings and of expositions this year show a large attendance and complete "sell-out" of expositions. At no other time is it more important that the Ceramic Congress, with its Meetings and Exposition, be more largely subscribed to and supported.

Rather than one-third of the space being sold at this time, we should have been able

to report fifty per cent of the space sold. There have been no personal solicitations; all of the booth rentals to date have been the results of correspondence. You are urged to get behind this program.

RULES AND REGULATIONS COVERING THE ART EXHIBITION OF THE AMERICAN CERAMIC EXPOSITION

Division of Manufacturers of Glass and Chinaware

(1) Manufacturers are not limited as to the number of pieces to be shown.

(2) If the manufacturer is an exhibitor in the American Ceramic Exposition, pieces may be shown under his company name and also the designer's name, in case he so desires.

(3) If the manufacturer is not an exhibitor in the American Ceramic Exposition, then the pieces must be shown with the name of the designer only.

(4) There will be an entrance fee of $1.00 per article shown.

(5) Exhibit material must be shipped by express prepaid to "The Art Committee, American Ceramic Exposition, Public Auditorium, Cleveland, Ohio," where it will be opened by the committee, and its suitability for display passed upon by a jury.

(6) After the Exhibition, the material will be repacked by the committee and returned to the exhibitor by express collect.

(7) Awards of merit will be given by a jury for various divisions of china and glass. The divisions in which certificates of Award of Merit are to be given will be determined later.

(8) Two other provisions were discussed, one for a voting contest by the women in attendance at the Exposition as to the most beautiful dinner service shown. The other was that a committee from the Women's Club might be secured in order to pass judgment on the most beautiful service shown in the art exhibit.

RULES AND REGULATIONS GOVERNING PARTICIPATION OF CRAFTSMEN IN THE AMERICAN CERAMIC EXPOSITION

(1) Each craftsman is limited to 8 pieces.

(2) These must represent his own handiwork and must have been made within two years.

(3) The entrance fee for each craftsman will be $2.00. Checks should be made payable to M. M. French, Secretary, and mailed to her in care of the Art Institute of Chicago before February 10.

(4) For admission the Exhibition material must have the approval of a jury.

(5) The craftsman is requested to set a price upon the things he is willing to sell. A commission of 25% will be deducted from the sale price inasmuch as the entrance fee will in no way cover the cost of space or proper showing of the pieces.

(6) Awards of merit will be given.

(7) The following classifications will each have a certificate of award: (*a*) vases, bowls, and jardinieres, (*b*) lamps, (*c*) ceramic sculpture, (*d*) decorative objects, (*e*) art tile, (*f*) novelty sets (breakfast, porch, etc.), (*g*) mold-made objects of utility suitable for easy duplication, (*h*) plates.

(8) The Committee reserves the right to withhold the Award of Merit for any classification.

(9) Arrangement will be for the beauty of the Exhibition rather than by groups of each craftsman's work. A catalog will be provided.

(10) Material for display must be shipped by express, prepaid to "The Art Exhibit, American Ceramic Exposition, Public Auditorium, Cleveland, Ohio." Material will be insured while in the Auditorium but not in transit. Entry blanks will be sent early in January.

(11) After the Exhibition, material will be returned by express collect.

(Signed) Marion L. Fosdick,
Myrtle Meritt French,
Charles M. Harder,
Committee on Exhibitions

SUMMER MEETING, GLASS DIVISION, COVE POINT, MD., OCTOBER 4

The members of the Glass Division will hold a summer meeting at Cove Point, Md., on October 4, 1930. A. N. Finn, Bureau of Standards, Washington, D. C., is in charge of transportation from Washington, D. C., and should be notified so that suitable arrangements can be made.

Dr. Gehlhoff of the Osram Laboratories, Berlin, and Dr. Schott, from the Jena Glass Company will be present as guests. A good representation of the members of the Glass Division is expected to attend the meeting.

RESEARCH ON REFRACTORIES

This report is sponsored by the Research Committee of the Refractories Division of the AMERICAN CERAMIC SOCIETY.

First Report

This Committee's first annual report has been published in the *Bulletin of the American Ceramic Society*, May, 1930, on page 158.

The report contains a list of existing sources from which new information in this field may be expected, and a list of problems covering needed information on refractories. In addition it contains a brief review of work done by the Committee on Boiler-Furnace Refractories of the American Society of Mechanical Engineers. A supplemental list of problems is given. See p. 294, this *Bulletin*.

Purpose

This letter is addressed particularly to the physics, chemistry, and metallurgy departments of colleges and universities in general and not alone to the ceramic schools.

This Committee is interested in having people who undertake physical and chemical research, as an educational requirement, do high temperature research and particularly such research and experimentation as have to do with refractories. The information thus to be developed is needed, and there is room in industry for men who know how to develop and use such information.

The following suggestions are made to those who undertake this type of work.

Physics

To those undertaking physical research we suggest the determining of high-temperature physical constants of refractory materials, both pure substances and aggregates.

Metallurgy

Students graduating from metallurgical courses need a knowledge of refractories, and more particularly a knowledge of the effects of furnace design on refractories and the placement and control of the combustion in the furnace so as to gain maximum efficiency with minimum effect upon the refractories.

Hence, we suggest that metallurgical departments might well collect and correlate data on furnace design, and study the behavior of the various refractories that have been in use, making petrographic studies of slag attack on actual brick. As noted above, such studies are already being made for boiler-furnace refractories. Checking various phases of this boiler-furnace work should prove valuable in commercial use.

In the various iron and steel districts the study of the effects of furnace design and operation upon the refractories of the open-hearth furnace, the blast furnace, and accessory furnaces, including electric furnaces, should prove inviting fields to prospective metallurgists.

Likewise, in districts where copper and lead furnaces exist there are many "construction" and "operating" problems in connection with refractories, the study of which would yield valuable information.

Chemistry

Chemistry departments could usefully make studies of high-temperature processes in general, and particularly studies of the chemical reactions that take place between the common refractories and other materials at high temperatures. This might include such studies as the effects of various metals, sulphides, and oxides on refractories, and the disintegration of refractories by gases at elevated temperatures.

Ceramics

In the case of the ceramic schools, where there are several students each year doing work on refractories, some of the department heads have already expressed a desire to take one of the larger problems in this field and have students work on different parts of the problem and perhaps have other students check the results, either the same semester or the following term.

Committee's Work

This Committee is pleased to give any assistance it can in this field, such as suggesting problems for researches, and bringing into contact persons working on similar problems.

We can be of most help to those undertaking researches in this field if we know who you are and what you are doing.

Therefore, we should be pleased to have those who are doing research of general interest on refractories send us brief descriptions of the work they are doing and the apparatus they are using for the purpose. No information which may be sent us concerning research will be published by us without the sender's consent.

Papers

Some work on problems undertaken this fall should be ready for presentation at the February, 1931, Meeting of the SOCIETY. R. B. Gilmore, Chairman of the Program Committee, of the Refractories Division, will be pleased to list worthy papers for presentation at the February meeting.

Research Committee, Refractories Division, AMERICAN CERAMIC SOCIETY

Chairman, D. W. Ross, Findlay Clay Products Co., Washington, Pa.
R. B. Sosman, U. S. Steel Corp., Research Laboratory, Lincoln Highway, Kearny, N. J.
Vance Cartwright, Mellon Institute, Oakland Station, Pittsburgh, Pa.
R. A. Heindl, U. S. Bureau of Standards, Washington, D. C.
R. S. Sherman, Battelle Memorial Institute, 505 King Ave., Columbus, Ohio.

J. Spotts McDowell, Harbison-Walker Refractories Co., Farmers Bank Bldg., Pittsburgh, Pa.
L. J. Trostel, General Refractories Co., Baltimore, Md.
Chas. J. Geiger, The Carborundum Co., Perth Amboy, N. J.

SUPPLEMENTARY RESEARCH PROBLEMS

Fire Brick

(1) Aluminous fire brick deform greatly under load at high temperatures as compared with siliceous fire brick. Is the great deformation of the aluminous brick due entirely to the continued shrinkage of the aluminous materials as opposed to the long-continued expansion of crystalline silica? Is it due in part to differences in the nature of the interstitial glass or are there other contributing factors?

(2) Certain raw clays on being heated approximately to 1100°C, supposedly release free silica as cristobalite. One of the proofs that this is cristobalite is based on the fact that such material, when reheated, shows a decided thermal expansion at approximately 175 to 200°C. It is commonly accepted that cristobalite has a variable inversion temperature depending on its previous history, the inversion ranging from 200 to 275°C. As the sudden expansion in the case of these clays is largely below 200°C, is this merely another instance of the variable inversion temperature of cristobalite or is there some other explanation for this phenomenon?

(3) In their range of usefulness, increase in the temperature of firing of fireclay refractories increases the temperature at which they fail in both compression and transverse tests under constant load. What are the limits of this increase compared with the vitrification range of the material and with the silica-alumina ratio?

(4) Certain refractory clays tend to crack more in firing than do others. It appears probable that this cracking may be related to the expansion of the raw clays on being heated from room temperature approximately to 1000°C. A study of the thermal expansions of substantially quartz-free clays of varying silica-alumina ratio should be interesting in this connection.

(5) In substantially all quartz-free plastic refractory clays the porosity of the dry unfired piece decreases with increase in transverse strength of the raw dry piece and with the increase in ratio of silica to alumina. Additional data on this point should prove valuable in clay testing as standards from which to predict properties of new materials.

NEW MEMBERS RECEIVED FROM AUGUST 1 TO SEPTEMBER 1

PERSONAL

Robert K. Beck, 7511 Jeffries Ave., Cleveland, Ohio; Superintendent, Cleveland Brick & Clay Co.

Henry G. Begeman, General Manager, General Kiln & Furnace Corp., 225 Broadway, New York, N. Y.

Heinrich Gerhardt, Ceramic Engineer, General Ceramics Co., Keasbey, N. J.

Elliot P. Rexford, 2254 Fairfax Rd., Columbus, Ohio; U. S. Bureau of Standards.

William Singleton, Chief Research Chemist, Associated Lead Mfrs., Ltd., Research Laboratory, Brimsdown, Middlesex, England.

The record for membership workers for this month is as follows: W. E. S. Turner, 1; E. J. Vachuska, 1; F. A. Whitaker, 2; and Office, 1; total 5, personal.

ROSTER CHANGES IN AUGUST

CORPORATION*

Mansfield Vitreous Enameling Company, Roy D. Beck (voter), Mansfield, Ohio. (C. P. McFarland (voter).)

* Addresses within the parentheses represent the old address.

These roster changes which are published each month may be checked against the complete Membership Roster which appeared in the July, 1929, issue of the *Bulletin*. Copies of this issue may be obtained from the Secretary's office, price $2.00.

Terra Cotta Products Corp., Richard F. Dalton (voter), 401 Vernon Ave., Long Island City, N. Y. (New York Architectural Terra Cotta Co.)

PERSONAL*

Bennett, Dwight G., 628 Cleveland Ave., Elizabeth, N. J. (404 E. Daniel St., Champaign, Ill.)

Berkman, A. S., c/o J. D. Freeland, 53 Park Place, Room 406, New York, N. Y. (500 176th St.)

Callinan, J. Gavin, P. O. Box 202, Chillicothe, Ohio. (1984 N. Fourth St., Columbus Ohio.)

Cavanaugh, Dan J., The Hanley Co., Summerville, Pa. (State College, Pa.)

Cole, A. H., 456 Wealthy Ave., Grand Rapids, Mich. (1300 Leader Bldg., Cleveland, Ohio.)

Copp, Warren F., Testing Laboratory, Plant No. 2, Frigidaire Corp., Dayton, Ohio. (Columbus, Ohio.)

Crisfield, A. P., 2109 Eoff St., Wheeling, W. Va. (Atlanta, Ga.)

Doorn, Cornelius, 854 Montrose Ave., Chicago, Ill. (Alton, Ill.).

Drake, Arthur D., Rockford Brick and Tile Co., Rockford, Iowa. (Columbus, Ohio.)

Dressler, Philip, 950 North Negley Ave., E., E. Pittsburgh, Pa.; Swindell-Dressler Corp. (1543 E. Boulevard, Cleveland, Ohio.)

Given, Conrad W., Ferro Enamel Corp., Research Laboratory, Cleveland, Ohio. (Philadelphia, Pa.)

Haney, Howard L., Harshaw Chemical Co., Terminal Office Bldg., Carson St. and Terminal Way, S. S., Pittsburgh, Pa. (1945 E. 97th St., Cleveland, Ohio.)

Hansard, W. C., 732 Riverside St., Trenton, N. J.; Whitehead Pottery Co. (175 Lismore Ave., Glenside, Pa.; Enfield Pottery & Tile Works.)

Hasslacher, Geo. F., 24 Gramercy Park, New York, N. Y. (Roessler & Hasslacher Chemical Co., New York, N. Y.)

Kaeppel, Herbert V., 59 E. Van Buren, Room 1500, Chicago, Ill.; *Brick & Clay Record.* (407 S. Dearborn St.)

Kraner, Hobart M., Westinghouse Electric & Mfg. Co., Derry, Pa. (E. Pittsburgh, Pa.)

Nicholson, Clifford M., No. 4 Reinhorn Apts., 11th Ave., Regina, Sask., Canada. (1036 College Drive, Saskatoon, Sask.)

Pressler, E. E., 311 Essex St., San Antonio, Texas. (501 N. Central Ave., Chicago, Ill.)

Rhead, John, 764 Kimball Place, Columbus, Ohio. (112 N. Ardmore Ave., Bexley, Ohio.)

Robson, H. L., 8116 W. Rivershore Drive, Niagara Falls, N. Y. (1614 Roosevelt Ave., Richmond, Calif.)

Schaeffer, J. A., Eagle-Picher Lead Co., 305 St. Clair Ave., East St. Louis, Ill. (St. Louis, Mo.)

Schweickhardt, W. K., 3249 Lafayette Ave., St. Louis, Mo. (Box 2336, Auburn, Ala.)

Stein, Alan, Millfield, Polmont, Stirlingshire, Scotland. (Glenbervie, Larbert.)

Steinhoff, F. L., 59 E. Van Buren, Room 1500, Chicago, Ill.; *Brick & Clay Record.* (407 S. Dearborn St.)

Svec, J. J., 1304 Clinton Ave., Berwyn, Ill. (Carey, Ohio.)

Walworth, Chester A., Libbey-Owens-Ford Glass Co., Charleston, W. Va. (Libbey-Owens Sheet Glass Co.)

Wormhoudt, G. H., 7 Seward Place, Schenectady, N. Y. (Box P, Sta. A, Ames, Iowa.)

NECROLOGY

C. H. Muckenhirn

Word has been received of the death of C. H. Muckenhirn, president of the Filmolens Sales Company, on May 1. Mr. Muckenhirn has been a member of this SOCIETY since 1920.

Charles F. Gleason

Announcement has also been made of the death of Charles F. Gleason, vice-president of the Gleason-Tiebout Glass Company, Brooklyn, N. Y. Mr. Gleason was associated with this company and its predecessor for fifty years and had been a member of the AMERICAN CERAMIC SOCIETY for many years.

NOTES AND NEWS

RESEARCH IS OUR BEST SALESMAN[1]

BY E. J. KULAS[2]

Research vs. the Customer

We discovered that laboratory work is primarily of value as a competitive instrument soon after we had set up a research department some years ago. At the outset its work was altogether internal. Plan after plan was produced that would have ironed out manufacturing problems which were our own concern. But, to get the bulk of them into production, we soon found that it was first necessary to induce buyers of our products to make changes. The external factor was the controlling one and we had been giving it secondary consideration.

Accordingly, we made certain changes and today our laboratory is geared to consider customer or external requirements first. Its value to us has increased tremendously.

The attitude of customers toward our laboratory work has completely changed. When they saw it as a unit of production designed to increase our profits or to facilitate our manufacturing processes they were not interested. But even a new customer will listen to a salesman who has nothing to sell except the ability of his laboratory to improve something that the customer knows needs improvement. He will listen to the salesman and nine times out of ten he will coöperate not only with the laboratory but with the production department.

So much has been said and written about the value of industrial research that in theory there is no longer any resistance to the movement. Even in our most backward industries, the leaders at least recognize that there can be no progress without improvement of product and service, and no improvement without a continuous survey of the uses to which the product is being put and the additional needs it may be designed to serve.

What is happening, in my opinion, is that an increasing percentage of what business men call the firing line is being shifted into the laboratory.

The salesman in any manufacturing line today should have the backing and close cooperation of a well-equipped research department. In our experience it was not sufficient merely for these divisions to coöperate. To meet the new type of competition there must be a mutual understanding by research workers and salesmen of the competitive problem that each has to solve.

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[1] Abstracted from *Nation's Business*, September, 1930.

[2] President, Otis Steel Co., Midland Steel Products Co.

I am using the term "research" here in the sense of laboratory workers whose task it is to improve manufactured products or methods of manufacturing them. Heretofore, with few exceptions, that function has been regarded as an adjunct of production, and therein, I believe, lies its greatest limitation. A tendency develops in such a laboratory to make methods more convenient or profits higher for the direct manufacturing employer. The needs of the customer may not be overlooked, but inevitably they become secondary.

Changes Foreseen by Research

It is common knowledge among business men that with our present development of management and internal control, few enterprises lose volume or fail for reasons arising within their own organizations. The danger lies in external factors over which the management has no direct control. Therefore, it follows that progress and expansion as well as survival depend on the extent to which change is anticipated. Change, in the sense of improvement, is the chief function of a research laboratory keyed to sales.

In our own experience, the effect of such a research program is to set up what amounts to control of the external factors. It produces internal economies by its influence on these external factors. This influence becomes its objective, whereas it is only a by-product in a laboratory geared to production alone. Thereby it pays for itself in immediate savings. It pays again by making it possible to retain present customers, and in addition it gives the sales organization material far enough ahead of competition to make healthy growth and expansion inevitable, other things being equal.

This method of doing business likewise influences the perspective of the sales organization. The salesman is compelled to think in creative terms. It is human nature for every man on the firing line of sales to pay too much attention to what his competitors are doing. That leads him into offering something "just as good," and to attempt to make it better by a competition confined to price, which soon becomes ruinous to all concerned.

When five men go after an order on a price basis alone, all their employers are bound to lose. There is business enough for all five to succeed if all selling could be done on the theory that there is no competition except for improvement—which means laboratory competition.

CHICAGO DISTRICT ENAMELERS' CLUB

In October, 1930, the Chicago District Enamelers' Club will start its new season.

Five years ago this organization was formed, its purpose being to give the enamelers of the Chicago District a forum where once a month they could meet each other and "talk shop" over the dinner table. This idea seemed a good one then and met with fairly hearty support. During the last two years, however, the primary requisite for the success of the organization, *i.e.*, the attendance of the members, has been missing.

Nominal dues of $4.00 a year are paid and the treasury is in excellent shape, but the meetings have been sadly neglected.

This year the officers intend to make every effort to obtain interesting speakers. There is enough money in the treasury to pay the expenses of men who come to address the organization.

Members of the Club are asked to attend the meetings more regularly.

The meetings will again be held at the Fort Dearborn Hotel, usually the last Tuesday in each month, and will as usual start with a dinner.

M. E. Manson is president of this organization, E. R. Brauner, vice-president, and Frank E. Hodek, Jr., secretary.

CALENDAR OF MEETINGS

Organization	Date	Place
American Assn. for the Advancement of Science	December 29, 1930 to January 3, 1931	Cleveland, Ohio
AMERICAN CERAMIC SOCIETY	February 22–28, 1931	Cleveland, Ohio
American Concrete Institute	February, 1931	Milwaukee, Wis.
American Engineering Council	October	Washington, D. C.
American Face Brick Assn.	November 12–14	Asheville, N. C.
American Gas Assn.	October 13–17	Atlantic City, N. J.
American Mining Congress		
Western Division Meeting	October 13–18	El Paso, Texas
Annual Convention	December 1–6	Washington, D. C.
American Refractories Institute	October 24	Atlantic City, N. J.
American Society of Mechanical Engineers	October 13–15	French Lick Springs, Ind.
American Society for Testing Materials	June 22–26, 1931	Chicago, Ill.
Assn. of Iron and Steel Electrical Engineers	June 15–19, 1931	Cleveland, Ohio
Illuminating Engineering Society	October 7–10	Richmond, Va.
National Assn. of Mfrs. of Heating and Cooking Appliances	May, 1931	New York, N. Y.
National Electrical Exposition	October 6–11	New York, N. Y.
National Exposition of Power and Mechanical Engineering	December 1–6	New York, N. Y.
National Glass Distributors Assn.	December 2–4	Pittsburgh, Pa.
National Paving Brick Mfrs. Assn.	February 4–6, 1931	Pittsburgh, Pa.
National Safety Council	Sept. 29–Oct. 4	Pittsburgh, Pa.
New Jersey Clay Workers Assn.	December	New Brunswick, N. J.
Optical Society of America	October	Charlottesville, Va.
Scientific Apparatus Makers of America	May, 1931	Newport, R. I.
Taylor Society, Inc.	December 3–5	New York, N. Y.
Tile & Mantel Contractors' Assn. of America, Inc.	April 14–17, 1931	Milwaukee, Wis.
Western Canada Brick & Tile Assn.	December	Saskatoon, Sask.
Wisconsin Clay Products Mfrs.	October	Madison, Wis.

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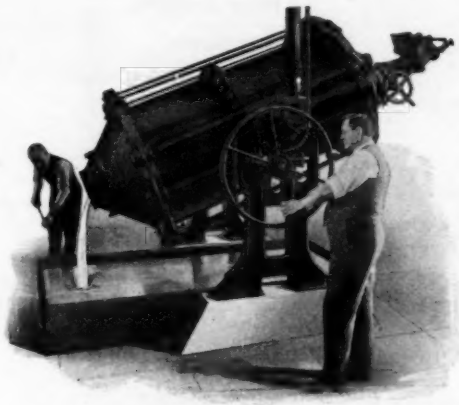

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C

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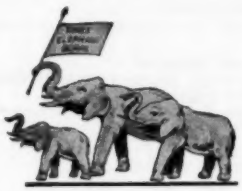

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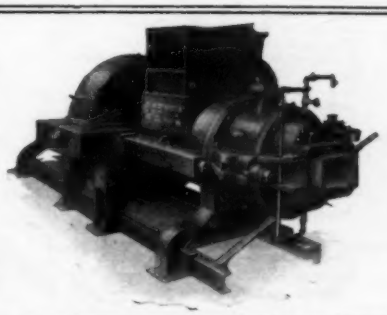

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THE CHALLENGER
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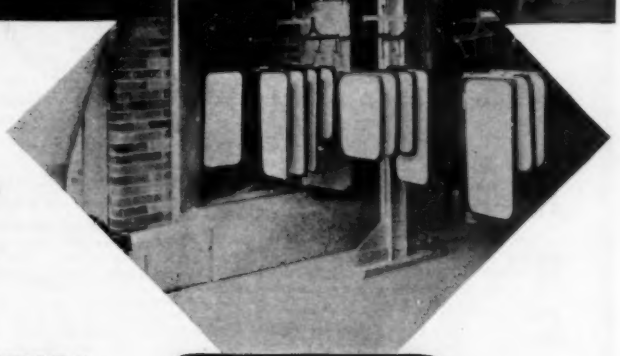

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ALUNDUM MUFFLES

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In the two large plants producing enameled ranges for a world famous distributor, Ferro Continuous Furnaces, equipped with Alundum Refractories to withstand severe conditions of the high temperature zone, are cutting production costs.

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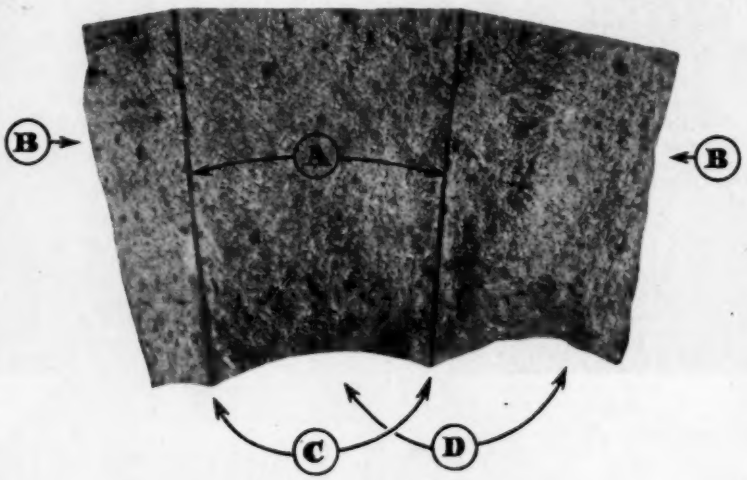
How are Your Arches holding up?

Compare the next ARCH that falls or is torn out, with section illustrated below—*this ARCH was laid in KROMEPATCH.*



A Thin even KROMEPATCH joints bond brick into a monolithic structure. Note absence of crumbling, fluxing, bubbling and squeezing out of KROMEPATCH.

B In tearing out this section, the brick broke while KROMEPATCH joints remained intact. The joints are stronger than the brick.

C KROMEPATCH protects brick by resisting destructive elements, preventing penetration at joints. Note how joints project, proving conclusively that KROMEPATCH is more resistant to abrasion and destruction than brick themselves.

D Brick wear back in center (concave) while strong KROMEPATCH joints project, giving protection where it is most needed and thus increasing service life of arch.

REMEMBER—Joint failure is caused by eithe crumbling or melting of bonding material.

Crumbling joints (material that lacks bond) allow heat to penetrate, exposing corners of brick which crack and fall out. This action repeats itself and soon joints are wide open and you need a new arch.

Joints made of clay base cements (lacking refractoriness) soften at low temperatures and flux sides of brick. Bonding material and fluxed brick bubbles from joint allowing heat to penetrate. Result—joints deeply cut out and short arch life.

KROMEPATCH Cement is primarily chrome ore—does not crumble, squeeze out or flux brick. Use it and avoid short ARCH and refractory lining life.

KROMEPATCH does prolong the service life of furnace linings.

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CHROME, MAGNESITE AND SILICA REFRACTORIES

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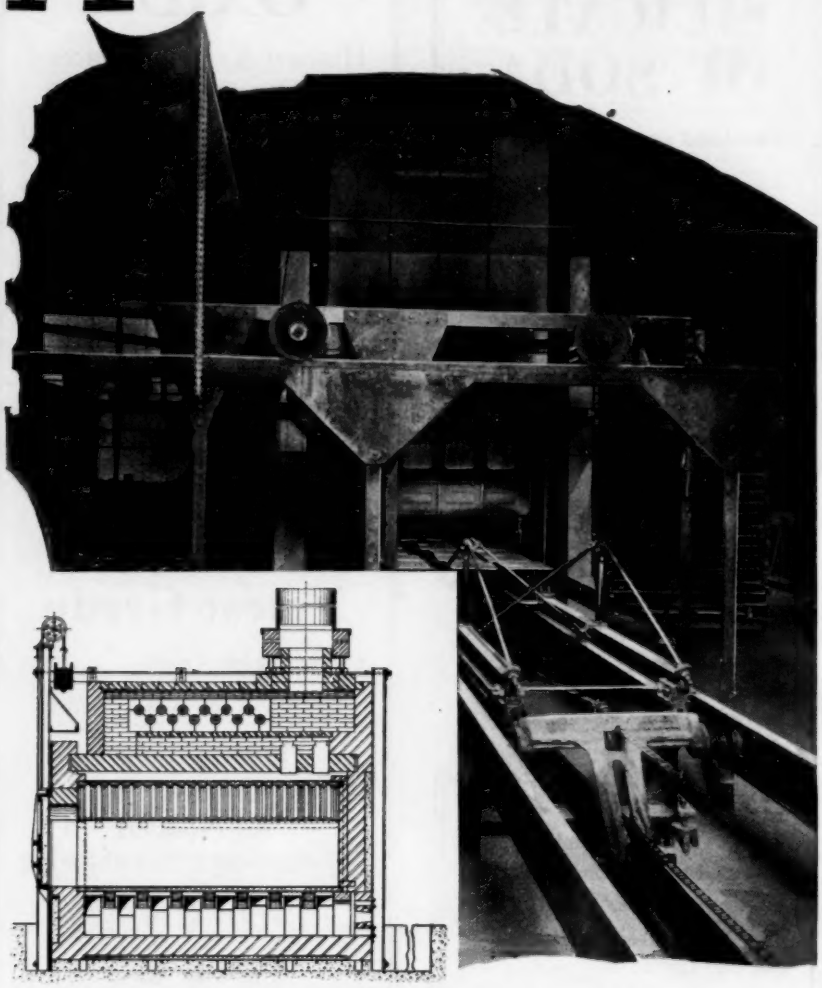

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REG. U. S. PAT. OFF.

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THIS successful combination scores again—this time at the plant of the Crown Stove Works, Inc. at Cicero, Ill.

And here are the mighty interesting performance and production figures—

Burning and drying cost—compared with old type furnaces and dryer—reduced 40 to 50%.

Operating on a 9-hour day the furnace produces 4,500 to 6,200 square feet second and third coat work—3,000 to 3,600 square feet ground coat work—20 to 22 gauge metal.

Oil consumption averages 10 gallons per hour.

The recuperator furnishes ample heat for drying all work produced—

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The "Carbofrax" muffle gives them a clean, uniform heat flow and losses are practically nil—plus an appreciable increase in production.

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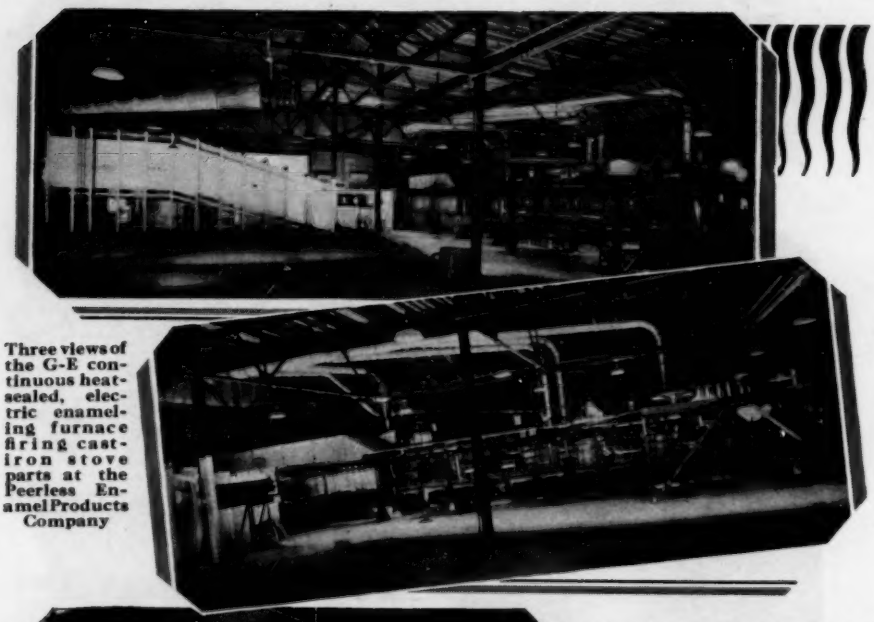

Three views of the G-E continuous heat-sealed, electric enameling furnace firing cast-iron stove parts at the Peerless Enamel Products Company

It isn't the cost of repairs that worries an enameler when his furnace breaks down - its the very serious loss of production. The General Electric continuous, heat-sealing enameling furnace assures continuity of operation because it is one of the most dependable pieces of equipment built. If this were not so, General Electric would not be using 14 of these furnaces in producing its refrigerators—a field of manufacture where continuity of operation is all-important.

GENERAL

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IN A G-E CONTINUOUS HEAT-SEALED FURNACE

With these RESULTS

THE Peerless Enamel Products Company of Belleville, Illinois—one of the leading jobbers to the stove industry—was, it is believed, the first to enamel cast-iron stove parts in a continuous electric furnace. And the equipment selected was a General Electric furnace with the famous heat-sealed firing chamber.

Eleven months after installation, the following results are reported:

1. Approximately 18 per cent reduction in the cost of enameling
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Future savings will show up, also, in the big reduction of maintenance and the absence of costly shutdowns, made possible by the combination of Electric Heat efficiently utilized in a furnace of sound design and construction.

If your production will warrant it, we can't conceive of an investment that will return quicker or more sustained dividends than one of these G-E continuous electric enameling furnaces. Be sure to write to the nearest G-E office for all the facts.

INVESTIGATE ELECTRIC HEAT

270-140 D

ELECTRIC

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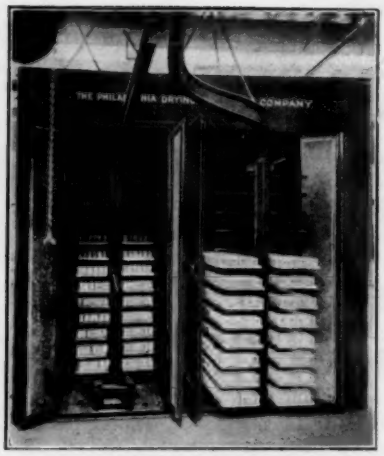

Stillage Type Dryer for pressware, saggers, etc. Note overhead conveyor.

More favorable drying conditions and increased production with "HURRICANE" DRYERS

"HURRICANE" Drying, with temperatures and humidity automatically controlled and air currents correctly distributed, generally results in faster drying, higher quality ware and less spoilage.

"Hurricane" Dryers are made in tray, truck and continuous conveyor types for enamel ware, pottery, insulators, refractory materials, etc.

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